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Ohio. State Board of Health

REPORT

OF

AN INVESTIGATION

OF

Water and Sewage Purification Plants in Ohio

Made Under Authority of an Act of Legislature,
Passed February 23, 1906

1906-1907

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LETTER OF TRANSMITTAL.

OHIO STATE BOARD OF HEALTH

SECRETARY'S OFFICE

COLUMBUS, February 1, 1908.

To the General Assembly of the State of Ohio:

Pursuant to the provisions of an act entitled "An act to direct the State Board of Health to examine and report upon public water purification works and sewage purification works in the State of Ohio," passed February 23, 1906, the accompanying report of the investigation and the conclusions drawn therefrom are herewith submitted.

Very respectfully,

C. O. PROBST, M. D.

Secretary.

By order of the Board.

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FOREWORD.

The State Board of Health was directed to investigate and report upon the water and sewage purification plants in Ohio under the provisions of the following act of Legislature:

AN ACT

To direct the state board of health to examine and report upon public water purification works and sewage purification works in the State of Ohio, and make an appropriation therefor.

Be it enacted by the General Assembly of the State of Ohio:

Section 1. That the state board of health be and it is hereby directed to investigate the construction, the methods of operation, and the efficiency of all water purification works and sewage purification works in use by cities, villages, and public institutions in the state of Ohio and to report its findings and conclusions to the general assembly not later than March 1, 1908.

Section 2. Said board in making this investigation may employ necessary assistance and for the purpose of carrying out the provisions of this act the sum of seven thousand five hundred ($7,500) dollars is hereby appropriated out of any moneys in the state treasury to the credit of the general revenue fund not otherwise appropriated, to pay the expense of such investigation during the year ending March 1, 1907, and a like amount is hereby appropriated for the expense of such investigation during the year ending March 1, 1908. (98 O. L. p. 11.)

In arranging for this work Mr. Philip Burgess, of Cincinnati, was engaged as special assistant engineer to examine water purification plants, and Mr. A. Elliott Kimberly, of Columbus, as special assistant engineer to examine sewage purification plants. They were assisted by Mr. T. L. Hinckley. Mr. R. Winthrop Pratt, chief engineer of the Board, had general supervision of the engineering work. The analytical work was done partly in the field and partly in the laboratory of the State Board of Health, the latter being under the direction of, first, Dr. Elmer G. Horton, and later, Mr. L. V. Parker, his successor, in charge of the Board's laboratory. The secretary and executive officer of the Board, Dr. C. O. Probst, was placed in charge of the investigation.

REPORT OF AN INVESTIGATION OF WATER AND SEWAGE PURIFICATION PLANTS IN OHIO.

INTRODUCTORY.

Ohio, through its State Board of Health, has given special attention to public water supplies and the pollution of streams. In 1893 the Legislature enacted that:

"* * * * * no city, village, corporation or person shall introduce a public water supply or system of sewerage, or change or extend any public water supply or outlet of any system of sewerage now in use, unless the proposed source of such water supply or outlet for such sewerage system shall have been submitted to and received the approval of the state board of health." (O. L. v. 90, p. 94.)

Since that time the Board has passed upon five hundred and eighty-five plans for new installations of water works or sewerage systems or for changes or extensions of those previously constructed.

The Board has used its influence and the powers of this act at all times to secure the introduction of safe water supplies, and to protect those in use against additional contamination.

The present investigation has revealed that the plans for purification plants, as approved by the Board, were in many cases materially changed as the work was under construction, and often to the distinct detriment of the plant. As the State Board of Health is required to approve all plans for water works and sewerage, it is essential, if public protection is to be provided for in this manner, that the Board should have a close supervision of all such sanitary works during their construction. This the Board has not been able to do heretofore from lack of funds.

In 1897 the Board began a systematic study of the sanitary condition of Ohio streams. This work was continued five years, and five special reports, comprising 1229 printed pages, and a number of maps, diagrams and tables, giving the findings and conclusions of this investigation, were published.

The present investigation, then, is but a continuance of the past work of the Board, all tending to secure pure water for public consumption, and to protect our lakes and streams from avoidable pollution.

The question of purifying public water supplies is of especial importance in this state. Ground water supplies of natural purity are in many places unobtainable for municipal use; and even in more favored localities the quantity available is insufficient for a large population. Our cities must largely depend upon our lakes and streams. Indeed, even at the present time fully 70 per cent. of the total population supplied with water in a public way, is using surface water. With our rapid increase of urban population many communities now served by ground water will soon be forced to turn to streams.

In the special investigation of Ohio streams, above mentioned, the Board reached the conclusion that no stream in Ohio was of sufficient purity, or could be so safeguarded against contamination, as to afford at all times a safe public water supply. The only exception might be the upper reaches of a few streams where small watersheds affording enough water for small cities, could, by careful policing, be kept free from contamination.

There is scarcely need for argument in favor of pure drinking water. The only question is, what constitutes pure water? Clear water, free from taste and odor, usually satisfies the public, but such water may be dangerously polluted. We do not know how far sewage may be carried in a running stream and contaminate a water supply below. In the famous controversy between the cities of St. Louis and Chicago, there was evidence to show the probability of sewage from Chicago affecting the river at St. Louis.

It can scarcely ever be safe at all times, at least, with conditions as in Ohio, to use unpurified water from a stream receiving sewage in any considerable amount. This means that most of Ohio's cities with water supplies of surface origin, must look to purification works for their protection.

In reviewing broadly this special investigation of water and sewage purification plants the main objects in mind were:

1. To discover those plants for the filtration of water or sewage that were inefficient, especially as regards water.

2. To study these with sufficient care to learn whether their inefficiency was due to faults in construction or operation, or both.

3. To interest the local authorities in making such changes in operation or construction as were found necessary for proper efficiency, and to suggest what these changes should be.

4. To determine, if possible, what points in the construction and operation of water and sewage filtration plants are essential in all cases for proper results, and what must be varied, to meet differences in local conditions affecting the problems of sewage purification at different places.

5. To acquire accurate data and information that will enable the Board to better perform its duty of approving plans for public works of

this character, and to be of greater assistance to communities seeking its advice in matters relating thereto.

6. To ascertain and separate the various items of cost in the construction and operation of such plants and, where possible, suggest cheaper methods of operation.

In pursuit of these objects a preliminary communication was sent to the mayor and council, board of public service or board of trustees of public affairs, board of health, city or village engineer, in the case of municipalities, and to the superintendent in the case of public institutions, where water or sewage purification plants existed, stating the objects of the proposed investigation, and asking for their cooperation. This was followed by a preliminary visit by the chief engineer and the special assistant engineers, and a conference with those connected with or interested in the plant to be studied.

It was emphasized at this visit that the first object of the Board was to render assistance, where needed and requested, with no intention of meddlesome interference, and second, to add to our knowledge of the subject of water and sewage purification, with special reference to conditions in Ohio. The Board desires to here express its sincere thanks to the many public officials and interested citizens who contributed to the success of the investigation. It is believed that in practically all of the places where investigations were carried on a more intelligent interest has been aroused in the successful operation of their respective plants.

The points of chief interest developed by the investigation, not purely of engineering interest, may be briefly stated as follows:

To render a polluted water safe by filtration there must be in the first place a properly constructed plant, specially designed for the kind of water to be treated. The prime object of the filter — the removal of disease-producing organisms — may be defeated by cheap construction, or by the omission of essential regulating devices.

Given a properly constructed filter, its continued efficiency depends upon constant, careful, skilled attendance, and the application of sufficient coagulant.

The large plants will probably always have such attendance, including a laboratory for daily, or even hourly, examinations at times, to keep check upon efficiency. This is out of the question for small plants, but a careful man of average intelligence can be so instructed that with central supervision and occasional, perhaps monthly bacteriological examinations of the plant, good and fairly constant results can be obtained.

With a polluted water supply an inefficient filter which removes the mud, giving a clear water, but which fails to take out dangerous microorganisms, is by far worse than none. The people accept the water as pure, being deceived by its appearance, whereas if there were no filter, it would not be used for drinking purposes or would be boiled. The use of a filter under such conditions should not be permitted.

The lesson learned from the study of sewage disposal plants is, that municipalities are usually reluctant to spend a sufficient amount to properly construct a plant. Furthermore, but little interest is taken in them after they are built, so that they are often badly neglected and not properly operated.

A point of much importance is that sewage purification plants, as ordinarily constructed and operated, give small protection to public water supplies taken from lakes or streams into which they discharge. That is, while they may remove the offensive properties of sewage, they only to a small extent remove disease producing organisms which render sewage polluted water especially dangerous for domestic use.

The investigation enforces one further point — the need for central control and supervision of public water supplies and the sources from which they are derived. This is provided for in House Bill No. 699 now pending before your honorable body, to which attention is respectfully directed.

There remain many interesting points in water and sewage purification requiring further study to develop. It is highly probable that much greater economy in operation is possible than now obtains. The coagulant is the most expensive part of mechanical filtration of water, the method that is almost exclusively used in Ohio. There is great need of further study of this question.

In ordinary sewage purification, as previously noted, disease producing germs are not removed, to any considerable extent. It seems likely that in many cases in order to protect public water supplies, it will be desirable if not necessary to remove these germs from the partially purified sewage. Some experiments showing that this can be done have already been made by this Board, in connection with the United States Department of Agriculture, and will be included in the completed report. This question should be fully worked out by further experimental studies.

In conclusion, the Board feels warranted in recommending, as the results of the investigation:

1. That further studies be made of the water and sewage purification plants of the state, and of the general subject of water and sewage purification as it relates to Ohio conditons.

2. That a special investigation and report be made upon each of the public water supplies of the state of surface origin where filtration works have not been introduced.

3. That this investigation should include a study of all streams and lakes used or available for public water supplies, which are receiving sewage, to determine the degree and extent of pollution from this cause.

4. That the State Board of Health be enabled to provide for the general supervision and frequent inspection, during construction, of all water works, sewerage systems, and water and sewage purification plants, so that any deviation from the plans as approved by the Board, that would

materially lessen their efficjency from a health standpoint may be prevented.

Respectfully presented,

C. O. PROBST, M. D.,
Secretary and Executive Officer.

By order of the Board.

General Report by the Chief Engineer

R. WINTHROP PRATT,
Chief Engineer.

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GENERAL REPORT BY THE CHIEF ENGINEER.

PRELIMINARY STATEMENT.

The purpose of this report is to discuss the general features of the investigation and to summarize from the reports of Philip Burgess and A. Elliott Kimberly, special assistant engineers, the principal results of the work. The various methods of water purification and sewage purification in use in Ohio are described by the writer; and with the idea of making the report more clear to the reader who is not familiar with the subject, there have been added brief statements relating to water purification and sewage purification in general. The purely technical features of the investigation, as they may be termed, are discussed in detail in the above mentioned reports of the special assistant engineers.

R. WINTHROP PRATT,
Chief Engineer.

GENERAL REPORT BY THE CHIEF ENGINEER.

SCOPE OF THE INVESTIGATION.

The general objects of the special investigation of water and sewage purification plants have been outlined in the report of the secretary, which precedes this report. These objects, in brief, consisted in obtaining all such data as would be of benefit to existing plants; as well as in securing general information, for the use of local officials contemplating the installation of water and sewage plants, and for the guidance of the State Board of Health in supervising the operation of present and future plants, and in acting upon future proposed schemes.

If the Board had, ten years ago, been directed to obtain this general information, the scarcity of existing plants would have made it necessary to study the subject by means of small experimental plants, as has been done by the Massachusetts State Board of Health for the general benefit of all cities and towns in that state, and as has been done by several of the larger cities in the United States previous to adopting plans. The subject has, however, except as regards certain details, passed beyond the experimental stage; and we now have opportunity for investigating full sized plants under the actual conditions which affect their operation. This has been the first investigation of the subject, of any considerable extent, so far as water purification is concerned, which has dealt entirely with existing plants instead of with experimental devices. As there are a number of large plants in Ohio as well as a variety of design, it has been possible to make the scope of the investigation very comprehensive and to include, in a practical way, studies of many important features of operation and construction.

One of the objects has been to establish interest among the local officials having charge of water and sewage plants, by impressing upon them the importance of properly and faithfully operating the plants in their care, and by endeavoring to arouse in them a feeling of greater responsibility. With this in view, the Board's engineers have at each visit consulted with the local officials who have been connected with the care of the plants; and by explaining to them features in the plants not previously understood, and by indicating the great importance with which the general subject of water and sewage purification is now considered by well-informed public officials, we have sought to accomplish the above object.

The matter of cost of operation, as well as of construction has been studied in great detail during the investigation, as this is probably the most important feature which is considered by local officials contemplating the installation of plants. This feature of the investigation has

been followed also with a view to showing wherein the cost of operation of existing plants could be reduced without interfering with the efficiency, and by this means to interest, further, local officials in charge of such plants.

In brief, the investigation has been conducted as follows: The special assistant engineers have during the twenty months from April, 1906, to November, 1907, made continuously a series of examinations and inspections of all water and sewage purification plants in this state. Each examination covered a period of from one to five days or more. During each examination there were made the chemical, bacterial and physical analyses necessary to determine the efficiency of the plants from these standpoints, and complete records were kept of all features relating to the operation, cost, and general efficiency of the plants. During the investigation, all information relating to the construction of the plants has been studied and recorded, and to supplement the data obtained by the Board's engineers, records of certain features of operation have been kept with considerable accuracy at a large number of the plants by the local managers.

The reports of the special assistant engineers describe the conditions leading to the installation of the various purification plants and also certain complete descriptions of their principal features, the usual methods of operation, and a discussion of the results that have been accomplished since the plants were installed. They conclude with a brief comparative discussion of the various features of construction and operation of the different purification plants studied, and the relation of these features both to the results obtained and to the cost of operation.

WATER PURIFICATION.

GENERAL STATEMENT AS TO WATER PURIFICATION.

PURPOSES.

Water purification plants are installed for three general reasons: First, to purify the water bacterially and to remove the disease producing qualities; second, to remove those physical defects, such as turbidity, color, tastes and odors, which render it objectionable for domestic purposes; and third, to remove hardness or to purify the water from a chemical standpoint. The first and second purposes usually apply to the same plant.

EFFICIENCY.

The efficiency of water filtration, or the degree of usefulness of the process, is measured by what may be termed the wholesomeness of the final product. A wholesome or safe water may be defined as one which contains no disease producing qualities and which is clean in appearance.

A water may be considered safe when the bacterial life has by filtration been so largely eliminated that it is as pure as water from the best natural sources of supply.

The total number of bacteria per cubic centimeter in the filtered water is a factor in determining its wholesomeness; and the presence or absence of the colon bacillus, which is indicative of recent sewage or animal pollution, is an important guide. A still more important index is the quantitative analysis for colon bacilli, by which is indicated the amount of sewage pollution. No sharp distinction can be drawn between a safe and an unsafe water. The analysis must be considered in connection with all conditions relating to the source of the sample and its subsequent treatment.

The physical characteristics of the filtered water are an important factor also in determining the efficiency of filtration. It must be free from turbidity, color, tastes and odors in order to be considered satisfactory or wholesome. Although a water will not directly cause disease on account of its poor physical characteristics, it will not be depended upon for drinking by any large number of people and may, therefore, necessitate the use of well waters which are often contaminated though clear in appearance.

Guarantees of efficiency, sometimes made by filter manufacturers, are of use principally in indicating the kind of work to be done by the plant, and do not necessarily insure a safe water. Such guarantees, if made, should be based on local conditions, and should specify fully the character of water guaranteed.

METHODS.

All practicable methods for purifying and clarifying water depend either wholly or in part upon filtration through sand. The two principal systems of filtration, according to popular classification, are the mechanical or rapid system and the slow sand system.

With the mechanical system the water, after being thoroughly coagulated by means of chemicals and partially settled, is passed at a relatively rapid rate (perhaps 125,000,000 gallons per acre per day) through beds of sand specially constructed to permit of cleaning at frequent intervals by back flushing. The cleaning effect of the back flushing is increased in most instances by agitating the sand either with large iron rakes or with compressed air. The word mechanical is used on account of the various appliances employed for coagulating the water and cleaning the sand. The chief item of expense, in operating this type of filter, is the cost of chemicals.

With the slow sand system of filtration the water is passed through beds of sand at a slow rate, i. e., about 3,000,000 gallons per acre per day. Usually no coagulant is used with this system, but the water is treated by sedimentation or by a rough straining before being applied to the

filters. With this system the impurities in the water are retained in a thin layer at the surface of the sand, and these are removed by scraping after the filter is drained. The labor necessary for cleaning this type of filter is the principal expense of operation.

The above two methods are the ones used principally in this country for water purification. The slow sand filtration is the older method of the two, having been used in England and Germany for many years. Where the raw water, however, contains large quantities of clay or mud, it has been found impracticable to operate slow sand filters on account of the necessity for very frequent scrapings of the sand. With muddy waters the mechanical filtration system is, therefore, most applicable; in fact, it has been developed principally to treat such waters. In general, mechanical filters cost less to install but more to operate than slow sand filters. Either system, properly designed and operated, will furnish a safe water.

At certain places, where natural conditions permit, it has been found feasible to construct "natural filters," or infiltration works. For instance, a natural bed of gravel suitably located in a river valley is thoroughly underdrained, and the flow of the river then diverted over this area and allowed to filter into the drains; or a crib or collecting gallery is placed well below the gravelly bed of the river and the water drawn from such gallery. The chief objection to such systems is the fact that their operation is not easy to control and that the efficiency may suddenly decrease, thus allowing contaminated water to reach the consumer without warning.

The above methods—mechanical, slow sand, and "natural" filtration—are for the purpose of purifying the water from bacterial, pathogenic and physical standpoints. To soften water requires quite a different process. This is done by introducing into the water such chemicals as lime and soda ash, and thus obtaining a chemical reaction with and a precipitation of the substances in the water which cause the hardness. These are then removed from the water by sedimentation and subsequent filtration. In this way it has been found practicable to reduce the hardness very materially and produce a water quite soft enough for domestic and boiler purposes. Industrial water softening plants are common, and municipal softening plants are coming into use. With a municipal plant it is at all times very important that only the proper amounts of chemicals be used. If excessive amounts are used the treated water will create objectionable deposits.

There are in addition to the above types of plants a few plants designed especially for removing from the water iron, acids, or chemical pollution. Municipal works for these purposes are rare.

WATER PURIFICATION IN OHIO.

As stated in the report of the secretary, the cities and villages of Ohio must depend for their water supplies to a large extent upon lakes and streams. Seventy per cent of the population in communities in Ohio having public water supplies, depend upon surface sources, which cannot be adequately safeguarded from pollution. Water purification is, therefore, a necessity.

At the present time there are in use or under construction in this state, water filtration plants at the following places, twenty-seven in number.

Batavia,
*Bellaire,
Bucyrus,
*Camp Perry,
Cincinnati,
*Columbus,
Conneaut,
Dennison and Uhrichsville,
Elyria,
Fostoria,
Gallipolis,
Geneva,
*Ironton,
Linwood Park,
Lorain,
Marietta,
Newark,
Oberlin,
Pomeroy and Middleport,
Rocky River,
*Sandusky,
Springfield,
*Toledo,
Upper Sandusky,
Vermilion,
Warren,
Youngstown,

The estimated combined population of the above places which are now supplied with filtered water is 661,000. This is thirty per cent of the urban population (population of cities and incorporated villages) and sixteen per cent of the entire population of the state. Within a year, when plants at all of the above places are completed, 1,071,000 persons or fifty per cent of the urban population will be supplied with filtered water.

For the reason that the river waters of Ohio and to a certain extent the water of Lake Erie belong to the turbid or clay-bearing class, mechanical filters have, in general, been proved, both by experiment and by actual use, to be most applicable to Ohio conditions. Another reason, of perhaps minor importance, which makes the mechanical system more applicable to the Ohio conditions is the fact that the waters of this state are usually of such chemical composition that they react satisfactorily with coagulants, the use of which is necessary with this process.

The mechanical system, therefore, has been adopted at all of the above places with two exceptions, namely, Fostoria and Camp Perry, where slow sand systems have been chosen. In two cases, at Columbus and Oberlin, softening processes have been included in the purification plants. There are, at Shelby and Garretsville, plants (not listed above) which have been installed simply for the purpose of removing iron from ground water.

* Plants under construction.

The development of the art of designing mechanical filters during the past ten or fifteen years is well shown in Ohio. At the beginning these filters and their accompanying equipment were sold by manufacturers as proprietary devices; but as this system of filtration began to be used by large municipalities and as patents on the process expired, the design was looked at in a broader way and was taken up as a special branch of engineering. At several of the Ohio municipalities careful engineering investigations have been made before adopting plans for filtration; and in this way the plants have been made to suit local conditions. Some of the smaller places have installed plants without intelligent preliminary study, and without proper detailed plans and specifications, with the result that these plants have proved to be both inefficient and uneconomical.

It is of interest to note that the water filtration plant of the city of Cincinnati, recently placed in operation, is the largest filtration plant of its type, not only in Ohio but in the world. The plant was designed after extensive experimental studies of the Ohio River water; and these studies have served as an important precedent in designing plants in Ohio and elsewhere.

Of the plants now under construction, the four largest are of the mechanical type, of concrete construction, and embody the latest designs in this type of filter. Those at Columbus and Toledo have a capacity of thirty million gallons and twenty million gallons per day, respectively, and are probably the fourth and fifth largest municipal plants of the mechanical type in the United States; while that at Columbus is the largest softening plant yet constructed. At Ironton there is being constructed a system of natural filtration, with intention of obtaining water from sand bars beneath the Ohio River. The plant at Camp Perry, which is to be operated only a few months each summer, is of the slow sand type. Five of the six plants under construction are very nearly completed.

EXAMINATIONS OF WATER PURIFICATION PLANTS.

Detailed examinations have been made of the twenty water filtration plants, including the Oberlin water softening plant, which have been in operation during the period covered by the investigation. Each of these examinations has consisted of from one to five days of continuous observation, and each plant has been visited on an average of four times during the work, the larger plants having been visited more frequently.

During each examination, samples of the raw, coagulated and purified water were taken at frequent intervals. By means of specially devised equipment for making chemical and bacterial field analyses, these samples were always plated and sometimes counted for total numbers

of bacteria, at the plant. In addition, determinations for turbidity, color, alkalinity, carbonic acid, and sometimes iron, were made in the field. Samples for the determination of *Bacillus coli* were, during the first part of the investigation, shipped to the laboratory, but later, by using bile media, it was found possible to make this determination in the field. The following is a summary of the analyses made during the investigation:

Total number of samples collected	1,503
Analyses of copperas solutions	115
Lime solutions	276
Aluminum sulphate	25
Determinations of total numbers of bacteria	1,431
Examinations for presence of *B. coli*	905
Determinations of turbidity	997
Color	814
Total alkalinity	1,139
Phenol alkalinity	415
Free carbonic acid	168
Incrustants	198
Iron	46
Chlorine	18

At the several examinations and inspections those features relating to the construction of the plants were studied and recorded; and complete records were kept of the quantities of water filtered, the rate of treatment, quantity of wash water needed, coagulant used, and all other features of operation which relate to the cost or to the efficiency.

One of the most important features, both from the standpoint of efficiency and economy, studied in connection with the work, has been the quality of alum used, as it was found at the beginning of the tests that very poor grades of this material were frequently purchased by the officials in charge. The question of the relative merits of alum, and copperas and lime, as coagulants, has been taken up in as much detail as possible.

During the work there has been collected data in regard to typhoid statistics; and at two places, Conneaut and Youngstown, there were made thorough detailed investigations of the relation of the filtered water to the number of typhoid cases and deaths. The information was obtained directly by the assistant engineer of the State Board of Health, and cases not reported to the local health authorities were investigated. The data obtained at these places, therefore, are of particular value.

REVIEW OF RESULTS OF EXAMINATIONS OF WATER PURIFICATION PLANTS.

The general results of the examination of water purification plants will be discussed, as far as possible, in corresponding order to that in which the objects of the investigation have been stated.

INEFFICIENT PLANTS AND REASONS THEREFOR.

Of the nineteen plants studied there were at the end of the investigation eleven which were producing an effluent which could be classed as safe and eight which were producing an effluent which could not be so classed. Three of the eleven have a but slightly polluted water to treat—that is to say, the work they are called upon to perform is not great. The results might have been different had these plants been treating a badly contaminated water.

The reason for the eight failures were, in most cases, poor construction; although in one case the failure can be attributed to poor operation alone. In the term *poor operation* are included those plants which are of inadequate construction or are outgrown; that is to say, the principles of construction may have been correct but the plant has been too small to treat the amount of water it was called upon to furnish. Most of the failures are due indirectly to lack of intelligent preliminary study. At several places in this state it has been found that the plant was cheapened during its construction by the introduction of inferior material, so that a satisfactory plant was not actually secured in spite of the excellence of the original plans. It is false economy to cheapen the design or construction of a plant, because money thus saved will probably be soon used up in increased cost of operation.

Economical operation of filters has been found impossible in many cases on account of poor design. This has been shown at several plants where the proper use of the coagulant has been prevented by the insufficient size of coagulating basins, where controlling and indicating devices were absent, and where the clear water well was so small that it was necessary to operate the filters at excessive rates during certain hours of the day in order to supply the demand for water.

The quality, amount and method of handling the coagulant are important features; and it has been found at several plants that the purification effected varied with the amount of coagulant used. A definite minimum amount should be used, even though the raw water be clear. Severe typhoid epidemics have occurred in this state on account of a desire to economize by using too little coagulant.

The necessity for proper training and intelligence of the filter operator has been shown by the investigation to be of utmost importance; and wherever possible every filter plant should have a laboratory, or at least the necessary apparatus for making regular examinations of the raw and filtered water. With the larger plants more complete and more frequent analyses enable poor work on the part of the plant or any portion of it to be readily detected. In case the small size of the plant makes it a distinct burden to have an expert in charge at all times, it is practicable to train an operator of average intelligence to make simple tests by which poor results can be detected, and to have him act under

the general supervision of a high-class expert who shall visit the plant at regular intervals, perhaps once a month.

Many of the Ohio plants, including all of the older ones, have been built by filter companies which have furnished a guarantee to insure proper results. These guarantees have not always been as useful as intended, for the reason that they have made the degree of purity of the filtered water depend too much upon the condition of the raw water. In one case there was guaranteed a certain percentage removal of bacteria; and although this guarantee was fulfilled, a safe water was not provided, as the filtered water still contained sewage bacteria. This indicates that the percentage of bacteria removed may or may not be a measure of the improvement in the water from a disease producing standpoint.

The principal use of a guarantee, therefore, is to indicate kind and quality of work to be expected from a given plant; that is, whether the plant is to simply render the water clean in appearance and remove some of the bacteria, or whether it is to effect a high degree of bacterial purification. A guarantee should, if used at all, be drawn up only after careful preliminary studies of the local conditions by a sanitary expert.

IMPROVEMENT IN WATER PURIFICATION PLANTS DURING THE INVESTIGATION—COOPERATION OF LOCAL OFFICIALS.

At the beginning of the investigation there were twelve plants which were not producing a safe water. During the investigation, through the work of the State Board of Health, with the cooperation of the local officials, this number was reduced to eight; and in addition, several of these eight were greatly improved. The old Lorain plant, being outgrown, was replaced by a new one.

At the beginning of the investigation some of the operators knew nothing about the principles of filtration in so far as these principles related to efficiency from a sanitary standpoint. No hesitancy was shown in operating the filters at any rate whatever, provided the water could be made to pass through; and little thought was given to other important features. One of the important results of the investigation has been the instructing of filter operators in the principles of filtration. Several of the plants have been improved through the use of a better quality of coagulant, this improvement being due to recommendations made by the State Board of Health. Another reason for improvement has been the fact that the Board has been enabled to study local conditions and to determine in each case the degree to which a given water should be purified in order to be safe.

By a thorough study of the water filtration plants, we have been able to point out to the managers certain defects, principally in operation but also in construction, and to give advice relative to their correction. A valuable phase of the work has been also to point out wherein the plants could be operated more economically without sacrificing efficiency.

In general, a feeling of greater responsibility has been created among local officials. These men were glad to receive advice from and to cooperate with the State Board of Health in regard to the improvement of their plants, and to learn more about the plants under their charge. The Board's recommendations were usually followed if the expense involved was not great.

ESSENTIAL FEATURES OF DESIGN AND THEIR RELATION TO EFFICIENCY AND ECONOMY.

Successfully designed filter plants are made up of a number of important parts, each of which has an important bearing on the efficiency of the plant as a whole. Each seemingly unimportant detail has a work to perform, and its failure may cause the plant to become inefficient, even though the remaining parts be working satisfactorily. The following essential features are discussed in the light of the special investigation, with the intention of pointing out their relation to efficient and economical operation, as well as of indicating those points which are applicable to all cases as compared to those which must be varied to suit local conditions.

Intakes. In planning a filtration plant, the first thing to be considered is the location of the intake. This has been rarely done in the past for the reason that filter plants have been added to existing water works. By locating an intake in a river above all local pollution, or in a lake beyond the influence of sewer outlets, a better water may be secured, and the filter plant itself will not be called upon to perform unnecessary work. In this way, not only can a purer effluent be produced, but the plant can be operated at less expense.

Choice of a Coagulant. Although hitherto not generally realized, the choice of a coagulant has an important bearing on the design, and this feature should, therefore, be carefully considered by the designer before drawing plans for a filter plant.

The coagulants which are most commonly used in Ohio at the present time are (1) alum, or sulphate of alumina; and (2) copperas and lime With the latter the copperas is, strictly speaking, the coagulant, but the lime must be added in order to insure its precipitation. Alum is used at the majority of the Ohio plants, but several of the largest use copperas and lime.

In choosing a coagulant, the question to be decided is, which will give the best results with the greatest economy? In deciding this question, too much weight has been given to the relative first cost and not enough to the relative efficiency and to the true economy. Preliminary experimental studies with both kinds of coagulants and with the local water are important.

In correctly operated plants which have been built for the use of copperas and lime, there have been obtained as good results, so far as the purity of the filtered water is concerned, as would probably have been obtained with alum. It has been found, however, that the handling of copperas and lime requires an operator of more technical and special experience than does the use of alum, and that when improperly used these chemicals may cause the condition of the plant to so deteriorate that it is impossible for a time to secure good results with any coagulant Larger amounts of wash water have been found to be necessary with copperas and lime than is the case with alum.

Coagulating Basins and Mixing Devices. The great importance of efficient coagulating basins is not generally appreciated. With mechanical filter plants, and especially those treating a turbid water, the basins must be depended upon to do a very large proportion of the work. The function of the basins is quite as important as that of the filters themselves. This should be given due weight by the designer.

A coagulating basin which is too small will not permit of securing the greatest benefit from the coagulant. Such a basin may cause the chemical reaction to take place in the filters and thus clog the sand. Furthermore, the investigation has shown that there is a distinct saving in the amount of coagulant necessary if ample time is given, under all conditions, for it to thoroughly react. Efficiency and economy both demand basins of sufficient size. A basin holding two hours' capacity is considered the smallest allowable size from a hygienic standpoint, while a basin of four to six hours' capacity is none too large for economical operation.

Provision should be made for properly controlling the application of the coagulant and securing a thorough mixture with the water before the latter enters the coagulating basins. These should be so designed as to make available their entire capacity; and this may be accomplished through proper placing of inlets and outlets, or, if necessary, by baffling. The level of water in the coagulating basins should be but little if any above the level of water on the filters, and the channels conveying the coagulated water should be of ample size to prevent the breaking up of the coagulated masses. With some plants provision is made for settling the water previous to the application of the coagulant. This may sometimes be advantageous.

Capacity of Filters. Inadequate filtering area is a very common cause of the failure of plants, and conversely, an ample or apparently excessive capacity, based on usually accepted rates, has been the salvation of many plants at times when the water was especially difficult to treat. A plant can be more safely and economically managed if it is never necessary to overload it.

The number and size of filter units is largely a matter of convenience and economy and may be controlled by local conditions. Enough units

should be provided so that one or two can be cut out of service at any time without causing the others to operate at excessive rates, taking into account the available storage for filtered water.

Facilities for Washing. Properly designed and efficient equipment for washing filters is very important. Filters have invariably been found to become foul with inadequate washing, and this prevents proper purification. Unless the strainer and collecting system is of ample size to suit the rate of application of wash water for which it is designed, uneven distribution will result, with the effect of placing all the burden on a portion of the filtering material. Also a needless waste of wash water results from inadequate washing facilities. The wash water troughs and sewer connections which carry away the soiled wash water should be of ample size, and the arrangement of the filter should be such that all parts of the surface can be readily inspected by the operator.

In designing the washing equipment there should be considered the relative advantages, under the local conditions, of using air or other agitation, or of depending entirely upon the wash water for cleaning sand. With whichever system is adopted, the design of the piping and washing devices should be made consistent therewith.

Miscellaneous Equipment. There are miscellaneous accessories to a mechanical filter plant, each simple in itself, which add greatly to the precision and ease of operation, and therefore increase the general efficiency of the plant. These are rate controllers, loss of head gages, hydraulic and electric valves, facilities for readily sampling water from each filter, and conveniently arranged operating stands, having valve indicators and loss of head gages attached. In addition, the general design of the pipe gallery is very important. There should be ample room for removing parts, and all piping and valves should be accessible at any time.

Storage for Filtered Water. The filtered water basin, or clear well, should be of such capacity that it will never be necessary to operate the filters at excessive rates, even when there are unusual drafts upon the water system, such as is in case of fire. The clear well should be so constructed and located that its contents can never be contaminated by ground or surface water through leaky concrete walls, floors or roofs. Where possible, it is safer to go to a slight additional expense and locate the clear well away from the pipe gallery and filters, instead of underneath them. Where the amount of available land makes it necessary to place the clear well underneath, every precaution should be taken against leakage through the floor of the pipe gallery. The clear well should always be covered, not only to prevent accidental pollution but also to guard against the growth of objectionable organisms which create tastes and odors in the water. It is, furthermore, desirable to provide baffles so that the filtered water will always be kept in circulation in the well.

COST OF FILTRATION.

General statements relating to the cost of water filtration must be very broad, for the reason that local conditions, such as size of plant, proper design, use of supplementary unfiltered supplies and relation of output to capacity, control the matters of cost to a great extent.

With the larger plants, other things being equal, the cost of filtration per million gallons is less than with the small plants, for the reason that there are certain fixed costs which apply in any case.

As has been suggested in the discussion of essential features of design, a poorly designed or constructed plant or one of insufficient capacity costs more per million gallons to operate than one which is of proper size for the service required. On the other hand, if the plant is much too large, the interest charges on the excessive construction will increase the unit cost of filtered water.

It will be readily seen that with filter plants, as with manufacturing plants, intelligent operation reduces the cost. By the use of a good quality of coagulant, in correct amounts, and by watching closely the wash water, fuel and labor items, the expenses of operation may be kept at a minimum.

In general, the cost of filtration, by the mechanical system, has been found by our investigation to range from $3.50 to $14.00 per million gallons, or from twenty to forty cents per year per person supplied. These figures include approximate interest charges and represent the extra cost of purifying the water above that necessary for furnishing it unfiltered.

From another viewpoint, the cost of filtration is much less than the value to a city of a safe water and one of clean appearance. With an unsafe and dirty public water supply, the public health is affected, the people spend large sums for spring water and distilled water, besides having to operate unsatisfactory household filters. The cost per capita on this account is much greater than would be necessary to pay for properly filtering the supply at a municipal plant.

RELATION OF EFFICIENT FILTRATION TO TYPHOID FEVER.

It has been found in Ohio as elsewhere that where a sewage polluted water supply has been the cause of typhoid fever, the installation and proper operation of a well designed filter plant has greatly reduced the death rate from this disease. While records of deaths are kept by Ohio cities with a fair degree of accuracy, the records of cases are difficult to obtain from the local officials. In order to study the relation between the water supply and the number of cases of typhoid among its users, there have been made during the investigation two detailed studies of the conditions at Youngstown and at Conneaut. All informa-

tion relative to typhoid was obtained at first hand by the assistant engineer of the State Board of Health.

At Youngstown the investigation was made for the reason that the introduction of the water filtration plant did not reduce the typhoid fever death rate as much as was expected. After investigating in detail the history of over 200 cases which had occurred since the installation of the filter plant, it was found that the vast majority of these cases were due directly or indirectly to the presence of old-fashioned privy vaults and polluted wells and to the general unsanitary conditions of living among the poorer classes. The water supply, previous to the installation of the filter plant, had undoubtedly caused a large number of cases but had been by no means responsible for all cases. [For a detailed report of this investigation see Annual Report State Board of Health, 1906.]

The Conneaut investigation showed conditions different from those at Youngstown. At Conneaut a detailed study of all the cases of typhoid which had occurred for a period of three months showed that nearly all these had been infected from the public water supply. The filtration plant at this place, although adequate to sufficiently purify the lake water under some conditions, failed to do so when northeast winds brought additional pollution over the the water supply intake. It was during such periods of poor efficiency of the filter plant that most of the cases occurred.

It might be added that definite recommendations for correcting the conditions were given by the State Board of Health to the authorities at both the above places. No improvement has yet been made at Youngstown; but at Conneaut both the city officials and the managers of the water works have promptly taken action, in accordance with the recommendation of the Board.

SEWAGE PURIFICATION.

GENERAL STATEMENT AS TO SEWAGE PURIFICATION METHODS.

In beginning, it is desirable to say a word in regard to the composition of sewage itself. Generally speaking, sewage is water containing less than one-tenth of one per cent objectionable organic matter. This small portion, however, is largely in solution or is in a suspended or finely divided state, and this accounts in part for the difficulties of sewage purification. Some sewages are much more dilute than others.

The chief methods for purifying or partially purifying sewage are, according to popular classification, broad irrigation, intermittent sand filtration, coarse grain filtration, chemical precipitation, treatment in septic tanks, and treatment by sedimentation. The first three are final or complete processes. Sewage purification plants invariably include two or more of the above methods, usually a preliminary process followed by one or perhaps two final processes.

With broad irrigation the sewage is distributed in relatively small quantities over large areas of land, which may or may not be under cultivation. The sewage of from one hundred to three hundred persons can be purified on one acre of ground by this method. With intermittent sand filtration the sewage is filtered through specially prepared beds of sand, three to five feet deep, at rates much greater than are allowable with broad irrigation.

There are two types of coarse grain filters; the contact filter and the sprinkling filter. The former consists of a water-tight basin filled with coarse material, such as coke, coal, slag or broken stone; wherein the sewage is purified by being held in contact with the material for the proper length of time by temporarily closing the outlet of the filter. The other type is the sprinkling filter, which consists in its simplest form of a heap of broken stone or other coarse material, five or more feet high, with top level. The sewage is sprayed onto the surface of the filter in finely divided streams and is allowed to trickle downward through the material.

Clarification by chemicals or chemical precipitation and treatment in septic tanks and in sedimentation basins are all methods for removing a portion of the suspended matter in the sewage, or in other words, clarifying it. These methods are classed as partial or preliminary processes and are not intended to render the sewage inoffensive to smell. Chemical precipitation has been used but little during recent years, owing to the expense of operation. Plain sedimentation, which is the simplest kind of preliminary treatment, consists in passing the sewage at a relatively low rate of flow through a tank and allowing the heavier portion of the sewage to set-

tle. This heavier portion, or "sludge," is drawn off at fairly regular and frequent intervals.

The septic tank, properly designed and operated, has the advantage over other preliminary treatments in that such a tank is of sufficient size to allow the heavier solid matters, which accumulate at the bottom, to remain there for such a period that they begin to rot; and, attacked by bacteria, they are partially changed into liquids or gases, thus reducing the amount of solid matters to be handled when the tank is cleaned. The septic tank may be called a large sedimentation basin, which, in operation, is allowed to remain for long periods without cleaning.

Many schemes have been suggested or tried in the past for reclaiming certain substances in sewage, for the purpose of manufacturing fertilizer or similar products and making a profit on the investment. Experience has shown, however, that owing to the great dilution of the substances in the sewage, which might theoretically go to make up fertilizer, these substances cannot be removed profitably. The municipality, therefore, which intends to build a sewage purification plant should not be misled by the idea that it is self-supporting. Furthermore, where schemes have been tried for obtaining a revenue from sewage disposal, the efficient purification of the sewage, i. e., the producing of a satisfactory effluent, has been made a matter of secondary consideration. The only exception to the above occurs in the arid regions of our western states, where the land can be irrigated with sewage. This is practicable because the land is so dry that it needs the moisture of the sewage rather than the organic fertilizing ingredients.

SEWAGE PURIFICATION IN OHIO.

The dry weather flow of the rivers and streams in Ohio is usually entirely too small to inoffensively dilute the sewage which is discharged into them from cities, villages and public institutions. Sewage purification is, therefore, necessary if the farmers and other riparian owners living down stream are to be protected. Furthermore, the dry weather flow of the streams seems to be decreasing from year to year, and this makes the problem of sewage purification more and more important.

Geological conditions in Ohio are such that sand or gravel in sufficient quantities, and suitably located for constructing intermittent sand filtration areas, are rarely found. In regard to broad irrigation, the price of land is too high in localities near the cities, and furthermore, the rainfall in this state is such that the ground has little capacity for absorbing sewage. As regards the larger municipalities, at least, those processes which require the minimum area seem most desirable. At first there were built chemical precipitation works effecting only partial purification; but for the last six or seven years it has been the usual practice to use septic tanks as a preliminary process in connection with broken stone, coke, cinder, or sand filters.

The first sewage purification plant in Ohio was the chemical precipitation plant built at Canton in 1893. Five years later seven plants were in use by municipalities and public institutions. Up to the present time forty-six plants have been built or are under construction in the state; twenty-three are municipal and twenty-three institutional. These comprise plants at the following places:

MUNICIPAL PLANTS.

Alliance,	Geneva,	Oberlin,
Ashland,	Glenville,	Plain City,
Canton,	Kenton,	*Ravenna,
Clyde,	Lakewood,	*St. Marys,
*Columbus,	London,	Shelby,
Delaware,	Mansfield,	Westerville,
East Cleveland,	Marion,	Xenia.
Fostoria,	*Medina,	

INSTITUTIONAL PLANTS.

Alliance, Fairmount Children's Home.
*Bucyrus, Crawford County Infirmary.
*Camp Perry, Ottawa County.
Collinwood, L. S. & M. S. Railway.
Dayton, Montgomery County Infirmary.
*Delaware, Girls' Industrial Home.
Gallipolis, Gallia County Infirmary.
Gallipolis, State Hospital for Epileptics, Main Building.
Gallipolis, State Hospital for Epileptics, Cottage I.
Granville, Shepardson College.
Kenton, Hardin County Infirmary.
Lancaster, Boys' Industrial School.
Mansfield, State Reformatory.
Marietta, Washington County Infirmary.
Massillon, State Hospital for Insane.
Morgans, State Institution for Feeble-Minded Youth.
North Amherst, Ohio Quarries Company.
Sandusky, Soldiers' and Sailors' Home.
Shepards, St. Marys of the Springs.
Toledo, State Hospital for Insane.
Warren, Trumbull County Infirmary.
Warrensville, Cleveland Tuberculosis Farm Colony.
Wooster, Wayne County Infirmary.

When all of the forty-six plants included in the above table are in operation, the total population tributary to sewage purification plants in Ohio will be nearly 270,000. This is twelve percent of the urban population and seven percent of the entire population of the state. It will be noted that these percentages are small when compared to that of the urban population supplied with filtered water. One of the principal reasons why such a comparatively small number of persons is served by sewage plants is because the larger cities established their main sewer outlets before the State Board of Health was given jurisdiction over proposed sewerage plans, and hence, the cities were free to locate the sewer outlets as they chose. Furthermore, the larger cities are generally situated near rivers and lakes of such size as to afford considerable dilution for the sewage discharged.

Proposed plans for some fifty more plants, all municipal, have been

* Plants under construction.

approved by the State Board of Health, and it is expected that the construction of these will be commenced in the near future. With the completion of these plants, stream pollution in Ohio will be greatly checked, though by no means eliminated.

With the later proposed plants, as well as with the plants under construction, septic tanks and sprinkling filters have been adopted largely. The principle example of this type is the plant at Columbus, which will be completed within the next year. This plant was designed after a year's careful experimental investigation with the local sewage, and the results pointed to the feasibility and economy of sprinkling filters. Due largely to the results of the Columbus experiments, this system has been embodied in recent plans for works in Ohio and elsewhere.

TABULAR STATEMENT OF THE METHODS EMPLOYED AT THE 46 SEWAGE PURIFICATION PLANTS IN USE OR UNDER CONSTRUCTION IN OHIO, DECEMBER 1907.

No. of Plants.	Combined Population Tributary to Plants.	Preliminary Treatment (Preceded by Screening in all but Three Cases).	Final Treatment.
5	4,300	None	Intermittent filtration or similar treatment.
2	3,600	Sedimentation with continuous flow to filters	Intermittent sand filtration or similar treatment.
11	10,400	Flush tanks or storage reservoir	Intermittent sand filtration or similar treatment.
3	350	Septic tank	None.
1	3,000	Septic tank without dosing tank.	Intermittent sand filtration.
5	5,500	Septic tank with dosing tank...	Intermittent sand filtration.
2	500	Septic tank	Intermittent filtration through coke.
7	28,800	Septic tank	Contact filters.
1	8,000	Septic tank	Contact filters followed by intermittent sand filtration.
3	175,000	Septic tank	Sprinkling filters.
1	500	Septic tank	Sprinkling filters, sand filtration and chemical disinfection.
1	7,000	Septic tank	Continuous filtration with forced aeration.
2	9,000	Chemical precipitation	None.
1	9,000	*Chemical precipitation	*Contact filter followed by intermittent sand filtration.
1	3,200	Chemical precipitation	Sewage discharged over land to watercourse.

* Original plan. Plant abandoned after ten years' operation, during which the final treatment was generally omitted.

EXAMINATIONS OF SEWAGE PURIFICATION PLANTS.

During the investigation, examinations and inspections have been made of thirty-eight sewage plants which have been in operation, each plant having been visited one to eight times and the larger plants at least seven times. A total of fifty-one examinations and one hundred and fourteen inspections was made.

Each examination has usually consisted of continuous observations, covering periods of from twenty-four to seventy-two hours, of the principle features of operation of the plant, such as quantity of sewage treated, temperature observations, sludge measurements and the efficiency of purification as shown by chemical, bacterial and physical analyses of representative samples of the sewage and effluent. During these examinations there has been used additional assistance from the regular force of the State Board of Health, as well as from local sources. When an extended examination was not warranted, the plant was given simply a thorough inspection. After each visit the local officials were advised in regard to making necessary improvements or changes.

Following is a statement of the number of analyses made during the investigation:

STATISTICS OF ANALYSES.

Crude sewage	96
Septic sewage	88
Effluent from coarse grain filters	61
Effluent from fine grain filters	53
Total	298
Dissolved oxygen	613
Milk of lime	21
Sludge	9

Except in rare instances, during the investigation the greater part of the chemical analyses of samples collected during a test were carried out in the field with the aid of a portable laboratory. A complete analysis comprised the following determinations: Oxygen consumed, nitrogen as organic matter, free ammonia, nitrites and nitrates, chlorine, total and volatile suspended matter, fats, putrescibility, and dissolved oxygen. Of these determinations oxygen consumed, nitrogen as free ammonia, nitrites and nitrates, chlorine, dissolved oxygen and putrescibility regularly formed a part of the field work. The remaining constituents were determined on chloroformed samples expressed to the State Board of Health laboratory.

During the series of visits made by the special assistant engineer there was obtained at each place the necessary plans and general information regarding the sewerage system and the purification works for

compiling a complete description of them. In addition to the data obtained directly by the representative of the State Board of Health, the officials in charge at many of the plants have kept, upon blank forms furnished to them, daily records of the quantity of sewage treated, records of temperature, as well as of other features.

At one or two places the attendants have been taught to make simple chemical and physical tests of the effluent, in order to determine daily the efficiency of purification. To assist the attendants in this work, incubators for making putrescibility tests were furnished by the State Board of Health to three of the plants. Samples of the purified sewage, collected daily, were kept at body temperature for periods of twenty-four hours, and if no odor was given off by the effluent after incubation, the indication was that the plant was effecting a sufficient degree of purification. Other simple tests were sometimes made by the operators.

SUPPLEMENTARY STUDIES.

Supplementary to the special investigation of sewage purification plants, the Board has made, during the past eight months, a study of the practicability of using chemical disinfectants for the final treatment of sewage, i. e., for the treatment of effluents from sewage plants. This work was done cooperatively with the United States Department of Agriculture, Bureau of Plant Industry, the expense being divided equally between this department and the State Board of Health. At Shelby the problem of purifying acid iron wastes from the Shelby Steel Tube Works, being closely related to the purification of the village sewage, was investigated thoroughly by the State Board of Health. As indicated in the table of contents, each of the above supplementary investigations has been made the subject of a full detailed report.

REVIEW OF RESULTS OF EXAMINATIONS OF SEWAGE PURIFICATION PLANTS.

As with water purification, the results of the examination of sewage purification plants will be presented with the intention of showing the extent to which the objects of the investigation, previously discussed, have been accomplished.

GENERAL EFFICIENCY OF PLANTS.

At the end of the investigation twenty-five plants were classed as satisfactory; that is to say, they are accomplishing the purpose for which they were designed, by preventing a nuisance in the stream receiving the treated sewage. Thirteen plants were not satisfactory. Few if any gave cause for complaint by reason of offensive odors arising from the plants themselves. As there have as yet been placed in operation no plants which are intended to effect high bacterial purification, or to disinfect the sewage, efficiency from this standpoint is not considered.

Reasons for Failure. Ignorance and carelessness in operation, and even absolute neglect, together with outgrown plants, are responsible for most of the failures. In some cases the plants have been built on wrong principles, but usually they are sufficiently correct in design to permit of obtaining good results if properly managed and if not worked beyond their capacity. The failure on the part of operators to understand the principles of sewage purification and the consequent failure to manage the plant properly is largely due to the fact that the engineer who designs and builds the plant is not retained long enough to test it or to instruct the future operator as to its workings. In some cases there has been left by the builder the erroneous idea that the plant is practically automatic. Little thought is given to the necessity for increasing the capacity of the plant as the sewage changes in character or increases in volume. Frequently, lack of provision for future development of the original design has made an enlarged plant difficult and expensive to secure.

Comparison of Methods. Viewing the matter solely from the standpoint of preventing offensive pollution of the streams of the state, that is, from the standpoint of producing a non-putrescible effluent, the investigation has shown that intermittent filtration through sand or other fine material, such as crushed coke or cinders, is the most satisfactory method. Of the twenty-five plants which at the end of the investigation were producing a satisfactory effluent, seventeen employ this type of filtration. From another standpoint, out of twenty-three sand filtration plants (using this as a general term for filters of fine material), eighteen were satisfactory; of fifteen plants of other types, such as contact filters, miscellaneous coarse grain filters, septic tanks alone, and chemical precipitation, only six were satisfactory. It is true that the twenty-three fine grain plants include several small institutional plants, but the sewage from these is generally quite as difficult to treat, at a given rate, as is municipal sewage.

The fine grain filters have in many cases purified the sewage considerably beyond the non-putrescible limit and to a degree which could not be expected with any of the other methods. On the other hand, two or three of the contact filter plants have produced effluents which have entirely fulfilled the requirements of local conditions and which have been sufficiently satisfactory. While, therefore, filtration through sand or other fine material has served to better protect the streams of Ohio and gives better bacterial purification than other methods, yet where the cost places this method beyond the means of the municipality (as is usually the case with the larger plants), and where a high degree of purification is not necessary, coarse grain filters, if amply and correctly designed, may be installed with safety.

Odors. In regard to odors from sewage plants, considered independently from the character of the effluent produced, our investigations

have shown that this feature has not been an important one and that with a well designed plant it can be controlled by intelligent management. The degree of offensiveness of odors and the distance penetrated by them are largely affected by the condition of the atmosphere. Odors more or less objectionable may arise from scum or from freshly deposited sludge, when the latter is exposed to the air, as is done when septic or settling tanks are cleaned. This usually affords no cause for complaint, however. Odors may be caused by the aeration of septic sewage, if the latter has been retained too long in the tanks. No odors need be caused from the filters, whether they be of sand or other material, if the sewage is applied intermittently in suitably proportioned doses and the surfaces of the filters are kept reasonably clean.

IMPROVEMENT IN SEWAGE PLANTS DURING THE INVESTIGATION.—ATTITUDE OF LOCAL OFFICIALS.

At the beginning of the investigation some two-thirds of the sewage purification plants, including most of the larger ones, were found to be defective in regard to features of operation or design, or both. Municipal officials were found to have little interest in sewage purification, because it is a matter which benefits their neighbors down stream rather than themselves. Furthermore, most plants have been built by reason of complaints from persons living outside of the community, and under protest from the local officials. This has created a desire to build just as small and cheap a plant as possible, to have it operated by unskilled attendants, and to allow it to become outgrown. The importance and interest given to the sewage purification plant by local officials was found, for the above reasons, to be much less than the interest given to water purification plants by such officials.

The State Board of Health has had during the investigation no power by which changes could be demanded in the methods of operation or in the construction of any plant. Requests by the Board, however, supplemented by personal visits by its engineers, have resulted frequently, though not invariably, in arousing the interest of local officials and establishing in them a feeling of greater responsibility. As a result, eleven plants, or one-half of those unsatisfactory at the beginning, were, during the investigation, made efficient, or were considerably improved. By continuing the investigation and with perhaps increased authority on the part of the Board, it is believed that the local officials would take still more interest and that all plants would soon be placed on a satisfactory basis. Furthermore, the fact that municipal officers in Ohio are likely to change every two years makes it necessary that new and inexperienced officials receive proper guidance in managing the works coming under their charge.

SOME IMPORTANT FEATURES RELATING TO THE DESIGN OF SEWAGE PURIFICATION PLANTS.

The following are some of the most important features relating to the design and consequently to the efficiency of sewage purification plants, which have been discovered or emphasized by the special investigation.

Preliminary Study of Local Conditions. The first and broadly speaking, the most important step to be taken by local officials who are undertaking to solve the problem of sewage disposal is to secure the services of a capable engineer thoroughly experienced in this line of work. Under his direction there should be studied all the local conditions, including available local filtering material, quantity and character of existing sewage and degree to which it must be purified, design of existing sewerage system, and suitable location for the plant as regards both topography and distance from habitations. After giving due weight to all these features, it is then possible to determine the most economical and efficient type of works for the place in question.

Screens. Screens afford a simple means for efficiently and economically effecting the removal from the sewage of a certain amount of the coarser suspended matters, and they should be provided as a first step in all sewage purification schemes. The size or mesh of the screen should be made to fit the local conditions, giving due consideration to the fact that very thorough screening means increased expense, and that this may overbalance the cost of removing the suspended matters in the subsequent processes.

Preparatory Treatment.—Septic Tanks. Preparatory treatment refers to chemical precipitation, septic tanks and sedimentation basins, all of which are used for the purpose of removing suspended matter in sufficient quantities to secure the economical working of the filters which receive the tank effluent.

Chemical precipitation plants and sedimentation basins, especially the former, have been shown to be unnecessarily expensive on account of the cost of chemicals with the former, and the cost of sludge disposal with both. Septic tanks afford usually a simple means for not only clarifying the sewage, but, to a large extent, for disposing of the sludge. They may be used, therefore, where no extraordinary conditions obtain, as a means of preparatory treatment.

The tanks should not be too large, as long retention, except in case of weak sewages, produces foul effluents. Any putrefactive change in the effluent as it passes through the tank is a disadvantage, not only on account of the odors but because its final treatment is made more difficult. The principal septic tanks now in use in Ohio have been designed on a basis of holding twenty-four hours' flow. Fortunately, the sewage at these places is quite weak and has not been rendered foul by being held

so long. With sewages of ordinary strength, it is believed that tanks holding eight to twelve hours' flow are large enough.

At several places the sludge from the bottom of the tank is from time to time heaved to the surface in large masses, which when not held back by thorough baffling, pass to the filters with the tank effluent and tend to cause objectionable clogging. This action is especially violent in the spring and summer when the temperature is most favorable to bacterial life and the formation of gas. Tanks should always be divided into units, so that when one unit acts in the above manner it can be cut out of service.

Although the sludge disposal problem, as discussed above, is greatly reduced by the use of septic tanks, it is nevertheless necessary to provide some means of sludge disposal with all plants. Usually a rough filter or a leveled area of ground will be sufficient. The length of periods between necessary cleanings of a tank varies, as shown by the investigation, from a few months to four years or more, depending on the character of the sewage and size and design of tank.

Regarding the necessity for covering septic tanks, it may be said no offensive odors from the contents of the tanks, under normal operation, will travel more than a few hundred feet; but that if the tanks are drained down and expose undigested sludge, offensive odors will be created. Scum in sufficient quantities will also cause odors. Covers would not entirely prevent odors, as the sludge and scum would have to be handled, in any case, to a certain extent outside the tank. Covers have, however, the advantage, especially in the colder part of the state, of causing a more even temperature in the tank throughout the year; and where the sewage plant is exposed to the view of a considerable number of persons, as near a public highway or park, a much better and cleaner appearance is given to the entire sewage plant by covering the tanks.

Final Treatment. With this phase of the design more than with any other must be considered the degree to which the sewage should be purified. Also the area available for filters as well as the available head for operation must be given great weight in this connection.

Intermittent filtration through sand or other fine material, such as crushed coke or cinders, affords, aside from the disinfection processes, a method for producing the effluent of greatest purity. This method is, however, on account of the absence of suitable local sand, generally too expensive to be considered by the larger places. It has a valuable and practical field, where a high degree of purification is required, as in filters which treat as a finishing process the effluent from coarse grain filters. This process is also suitable for public institutions.

The rates of filtration have been found to vary with the strength and character of the sewage, with the size of filtering material, and with the preliminary treatment. In large plants the question of operating expense in cleaning the filters must be given due consideration in deciding

upon the rates to be used. It is not believed that sewage treated by septic tanks has any advantage over that treated by plain sedimentation, as regards the rates possible with subsequent filtration.

The practicable rates of filtration with the intermittent or fine grain filters studied is greater in summer time than it is in winter, on account of the difficulty of removing solid matters from the surface of the filters when covered with ice. An important adjunct to this type of filter is a dosing tank. With the rates of filtration usually employed, it has been found that only with such a tank can proper distribution be obtained. Furthermore, winter operation of the filters is greatly facilitated by applying the sewage in doses.

Contact filters, of which we have two successful examples in Ohio, afford means of producing on a comparatively small area of land and with little fall, an effluent which is sometimes but not always non-putrescible. Such effluents are only fit to discharge into streams having considerable dry weather flow, from which no public water supply is drawn. Our studies would seem to indicate the fact that only the weaker sewages can be satisfactorily purified by this method alone. When followed by secondary treatment on filters of sand or other material, this method may be used to advantage with stronger sewage.

The automatic controlling devices, usually employed with contact filters, have at the larger plants been generally satisfactory; but those at several of the smaller plants have proved to be absolute failures. These automatic controlling devices have at one place been omitted, and the flow of sewage is changed from filter to filter by the attendant with more or less regularity.

Sprinkling filters, as shown by the results of experiments in Ohio, afford a means of producing a non-putrescible effluent upon an area considerably less than that required for contact filters, and at a correspondingly less cost. The head for operating sprinkling filters, on the other hand, is greater than that required for contact filters. The absence at the end of the investigation of any completed sprinkling filter plant in Ohio has prevented the securing at first hand of any data regarding this method.

COST OF SEWAGE PURIFICATION.

Of the municipal plants now in operation in Ohio, the greatest in first cost (exclusive of land) is that at Mansfield, for which $66,000 was paid; while for that at Oberlin, the least in first cost, there was paid $990. The cost of construction of municipal plants, from a study of fifteen representative cases, ranges from sixty-two cents to $14.00 per capita based on population actually tributary when plant is operating at full capacity.

The annual cost of operation of these municipal plants ranges from three to ninety cents per person actually tributary, while the average

is thirty-four cents. These figures do not include interest charges, which in several cases equal or exceed the amount spent for actual maintenance. With institutional plants the real cost of operation is very small. There are no actual interest charges, and the plants can usually be operated by the inmates or by one of the employes of the institution, who may in addition have other duties.

Of course, comparison of cost of sewage purification at the different places must be used with great care, as local conditions have an important bearing on the matter. At some places it is necessary to operate a pumping plant, but the total cost at these places it not above the average of places where pumping is not necessary. Pumping, therefore, is not such a large item of expense as it is sometimes considered by local officials, who use it as an argument for the impracticability of purifying the sewage.

It will be noted from the above that the cost of purifying sewage is very small when compared with the benefits derived, as the matter of expense of sewage purification ought not to be given much weight as an argument for allowing cities to contaminate the rivers of the state.

REVIEW OF SUPPLEMENTARY STUDIES.

DISINFECTION OF SEWAGE EFFLUENTS.

Supplementary studies on this question have been made for the purpose of securing practical, economical and efficient methods for treating those sewage effluents which are being discharged into streams used as water supplies, it being well known that the ordinary processes of purification do not afford sufficient protection from a bacterial standpoint, especially when there is given no consideration to the matter of purification by dilution in the stream between sewage plants and water works.

The work was done on a practical scale. Four plants representing the different types of ordinary sewage purification methods were selected for the work, and the entire flow of sewage from each was treated, for the purposes of disinfection, for one or two days at a time. Accurate data were obtained upon the cost and efficiency of this treatment.

After thorough tests of the relative advantages of copper sulphate and bleaching powder as disinfectants for sewage effluents, it was found that the use of the latter was much more efficient and that it could be used without unreasonable expense, as a final treatment, when necessary, by any plant in the state which is now effecting a fair degree of purification. A complete account of the work done and the results obtained will be found in one of the detailed reports in this volume, and also in Bulletin No. 115, United States Department of Agriculture, Bureau of Plant Industry.

PURIFICATION OF ACID IRON WASTES AT SHELBY.

The disposal of the acid iron pickling liquors from the plant of the Shelby Steel Tube Company at Shelby has until recently been a continual source of complaint, and as these wastes have had an important bearing upon the purification of the sewage of the village, a brief account of their purification is herewith given.

Before the village of Shelby built a municipal sewage purification plant, these iron wastes were discharged into Black Fork, a small creek which passes through the center of the town. The wastes discolored the creek, and it was claimed by the riparian owners, made the water unfit for stock to drink. The tube company was found guilty in court of polluting the stream.

About a year after the municipal sewage plant was placed in operation, in 1901, the tube company connected its works with the village sewerage system in the hope of preventing further stream pollution. The result of this was that the acid iron wastes became so detrimental to the process of sewage purification that neither the wastes nor the sewage were properly disposed of, and the nuisance was simply transferred down stream.

In 1905 the problem of purifying the tube works wastes was studied cooperatively by the State Board of Health and the United States Geological Survey (see U. S. G. S. Water Supply and Irrigation Paper No. 186), with the result that the tube company installed a plant for treating its moist concentrated wastes by evaporation, thereby reclaiming considerable quantities of copperas. The returns from the sale of this copperas offset to a large extent the cost of treatment. The weaker wastes, however, known as rinse liquors, were still allowed to enter the sewers, to the detriment of the purification of the village sewage.

This condition was thoroughly investigated by the State Board of Health in the summer of 1906, and following the advice of the Board, the village ordered the tube works disconnected from the sewer system. As a result of the studies, made by the State Board of Health, of the problem of purifying the rinse liquors, the tube company installed a plant for neutralizing the acid and removing the iron from these wastes by means of lime. This plant is now in satisfactory operation, and the result is that owing to the purification of the tube works wastes as well as the improved efficiency of the sewage plant, due to the elimination of the above wastes from the sewage, Black Fork Creek is in better condition than it has been for years past.

GENERAL SUMMARY OF THE RESULTS OF EXAMINATIONS OF WATER AND SEWAGE PURIFICATION PLANTS.

(1) One of the most important objects of the investigation was to secure the support and co-operation of local officials in the management of the water and sewage purification plants under their charge. In most instances this has been satisfactorily accomplished.

(2) With the co-operation of the local authorities, great improvement has been effected not only in the management but in the equipment and construction of a considerable number of water purification and sewage purification plants.

(3) The general and detailed reports, in which are discussed all features relating to the operation and construction of existing plants, make available in readily accessible form a large amount of general data which will be of very great value to local officials and engineers who may in the future be called upon to solve problems relating to water or sewage purification.

(4) Similarly, the investigation has afforded to the State Board of Health a fund of information for its guidance in acting upon future proposed plans, as well as in giving advice in regard to existing plants.

(5) The investigation has indicated the necessity for the continuance of systematic examinations of existing plants in order that further improvements may be effected; that the interest of local officials may be permanently maintained; and that the State Board of Health may obtain, at first hand, information regarding the merits of new features in the art of water and sewage purification, as these are from time to time introduced.

(6) The great difference in local conditions in cities and villages, as found by the investigation, would indicate the desirability of placing water and sewage purification plants under the control of a competent central authority, with power to prescribe individual standards of efficiency for each water purification and each sewage purification plant. It would seem unjust to allow a community to discharge into a stream used as a public water supply, even though the water be filtered, any disease producing organisms, the destruction of which can be effected without unreasonable difficulty. In other words, the water filtration works should not be given an extra burden to perform. A central authority is, therefore, necessary to decide with equity to all concerned how much work shall be done by the sewage plant and how much by the water plant.

Report of Examination of Water Purification Plants.

BY

PHILIP BURGESS,

Special Assistant Engineer.

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REPORT OF EXAMINATIONS OF WATER PURIFICATION PLANTS.

INTRODUCTION.

This report contains a description of the general methods of conducting the field tests during the examinations of the water purification plants, followed by twenty detailed descriptions of the main features of the plants, their methods of operation, the efficiencies obtained, and the costs of installation and operation whenever such were available. The report includes twenty parts, in which are described the results of the investigations of the several plants examined, presented under the following general heads:

1. GENERAL FEATURES, STATISTICS RELATIVE TO MUNICIPALITIES.
2. HISTORY OF WATER SUPPLY, INCLUDING A DESCRIPTION OF THE ORIGINAL INSTALLATION AND CONDITIONS LEADING TO PURIFICATION.
3. DETAILED DESCRIPTION OF MAIN FEATURES OF PLANT.
4. EXAMINATIONS AND INSPECTIONS MADE DURING SPECIAL INVESTIGATION.
5. METHODS OF OPERATING PLANT.
6. CHARACTER OF RAW WATER.
7. EFFICIENCY OF PLANT.
8. COSTS OF INSTALLATION AND OPERATION.
9. DETAILED ANALYTICAL DATA.

Following these detailed reports is a general summary of the most important features that have developed during the investigation as relating to the art of water purification and its application to Ohio conditions.

METHODS OF CONDUCTING FIELD TESTS.

During the examinations there were kept in view three main points, the degree of purification necessary at each plant, the means that were available for its accomplishment, and finally the results actually obtained. In order to solve these problems it is necessary to know the general character of the raw water handled, the efficiency of the different parts of the plant in performing their separate functions, and finally the degree of purification obtained and the wholesomeness of the water supply, as indicated both by analytical data and by the prevalence of water-borne diseases among the consumers.

The conduct of the field examinations comprised two general parts, the determination of the methods of operating the plant, and the collection and analyses of samples of water in order to determine the results obtained. In the following discussion is shown, first, the general conduct of the field tests in determining the methods of operating the plant, followed by a description of the methods of collecting samples and of performing the analytical tests.

Operation.

A mechanical filter plant comprises five general features, low service pumps, means for applying a coagulant, coagulation and sedimentation basins or tanks, filters, and storage of water between the filters and high service pumps in the clear well. The satisfactory operation of each of the different units is essential in order to obtain efficient results.

Pumps. No attempt has been made to determine the duties of the pumps, but it has been endeavored to learn whether or not they were of sufficient capacity at all times. The actual quantity of water pumped was generally determined by reading the pump counters, and except in a few occasional instances, assuming as correct the rating used by the operators. From past records, where available, has been ascertained the yearly increase in the daily consumption, a very important factor as determining the future adequacy of the plant.

Means for Applying Coagulant. Two general methods have been employed to determine the quantity of coagulant used; one, the actual measurement of the charges and the quantity of solution applied, and the other, the determination of the chemical changes brought about in the water by the application of the coagulant. The former or direct method is necessary in all cases where copperas and lime are used as coagulants, as there is no direct chemical determination by which the quantity of coagulant applied may be measured. In such plants, measurements were taken of the rate of application of the solutions, and their strengths were determined by titrations. In the case of alum it is possible to determine the quantity of coagulant applied by measuring the reduction of alkalinity, and an inspection of the analytical data will show that frequent samples of the raw and filtered water were taken and their alkalinity determined. The reduction in alkalinity caused by the addition of a grain of alum was measured experimentally during the examinations by introducing measured quantities of alum into samples of water and determining the alkalinities both before and after treatment.

Coagulation and Sedimentation Basins. While the operation of the coagulating and sedimentation basins has been found of great importance in determining the efficiencies of the plant, their use requires but little attention by the operators. During the examinations the theoretical displacement was determined by measurements of the capacity and the average rate of flow through the basins.

Filters. The operation of the filters requires control of the rates of filtration, and an economical and efficient method of washing. During the examinations, frequent measurements of the rates of filtration were made by closing the inlet valve and measuring the rate of fall of the surface of the water in the filter. This was done by means of a specially graduated brass scale and a stop watch.

Measurements of the rate of application of the wash water were determined in a like manner by closing the valve in the drain during washing and then measuring the rate of rise of the surface of the water in the filter.

Clear Well. During the examinations there have been determined not only the total capacity of the clear well, but also the actual capacity that is available for draft during the operation of the plant. The working capacity has sometimes been found much less than the total storage and has been an important factor in determining the [illegible] of operation of the plant.

Collection of Samples and Analyses Made.

During each of the examinations, samples were taken at the plant at frequent intervals to determine the character of the raw, treated and filtered water. It was also endeavored to obtain samples from the distributing reservoirs and

mains, in order to determine the efficiencies obtained previous to the examination, and to learn by analytical evidence the previous character of the raw and filtered water. In this manner it has been found possible to determine irregularities in the operation of plants that might otherwise have been overlooked.

As shown in the report by the chief engineer, the analyses made during the examinations comprised determinations of the total bacterial content and presence of B. coli, turbidity, color, total and phenol alkalinity, and free carbonic acid; also occasional determinations of iron and chlorine. Determinations of incrustants were made on samples shipped to the laboratory.

Bacterial Analyses. The determination of the total numbers of bacteria has been one of the important parts of the investigations and 1,431 such determinations have been made on a total of 1,503 samples collected. Bacterial counts were in all instances obtained on samples plated in duplicate in the field immediately after collection. Agar medium was always used and it was prepared in accordance with the methods of the report of the Committee on Standard Methods of Water Analyses. The plates were grown 48 hours and if the examinations were of sufficient length, they were counted in the field; if not, the plates were shipped in specially designed boxes to the laboratory of the State Board of Health, where they were counted.

During the examinations, 905 samples of raw and filtered water were examined for the presence of B. coli. During the early part of the investigation, and until April, 1907, the examinations for coli were made on samples shipped to the laboratory in specially designed boxes. These boxes contained a sufficient quantity of ice to keep the samples cold for at least 24 hours. Examinations for coli as conducted in the laboratory were in accordance with the methods of the Committee on Standard Methods of Water Analyses.

In April, 1907, during a test at the Youngstown plant, an examination was made as to the efficiency of bile for the determination of coli. During this test, which lasted seven days, different quantities of the samples, of which 102 were analyzed, were transferred to fermentation tubes, incubated, and those subsequently showing gas formation carried through for confirmatory tests. Both bile and Smith solution were used on the same samples. The bile was prepared from fresh ox bile, which was first sterilized and then 1.5 per cent. of lactose added. It was then tubed and resterilized. Only those tubes containing the smallest quantity of the samples giving presumptive tests were carried through and out of 40 confirmatory tests, 78 per cent. were obtained using bile. While ninety per cent. of the tubes containing 25 per cent. or more gas gave complete confirmatory tests with bile, on the same samples, but 13 per cent. of the tubes giving gas with Smith solution gave confirmatory tests. These results indicate the probability of losing the coli with the Smith solution when present in small numbers and also the superiority of the bile media as a presumptive test.

Subsequent to the test at Youngstown, similar investigations were carried on in the laboratory of the State Board of Health and the results confirm in a general way those previously obtained.

On account of its greater accuracy and applicability for field work, bile media has been used for all coli determinations since April, 1907. Where possible, quantitative determinations of coli, especially in the raw water, were made in the field by using different dilutions of the bile media. The formation of 25 per cent. of gas in the fermentation tubes was considered a positive test, and in general the proportion of positive tests since bile was used has been much greater than when the Smith solution was used. The evidence obtained during the investigations at Youngstown and at the laboratory of the State Board of

Health indicate a probable error of 10 per cent. in the field work, where only presumptive tests were used.

In the examinations for coli in 50 and 100 c. c. samples there was first added carbolated dextrose in such quantity as to give .025 per cent. phenol, and 0.5 per cent dextrose. The samples were then incubated at 37 degrees for 24 hours, after which time loopfuls were transferred to bile fermentation tubes and the procedure then continued in the same manner as in that used for direct determinations. From the fact that coli were occasionally found in 1 c. c. portions and not in 100 c. c., it is apparent that the above method of enrichment is not as efficient as would be desired.

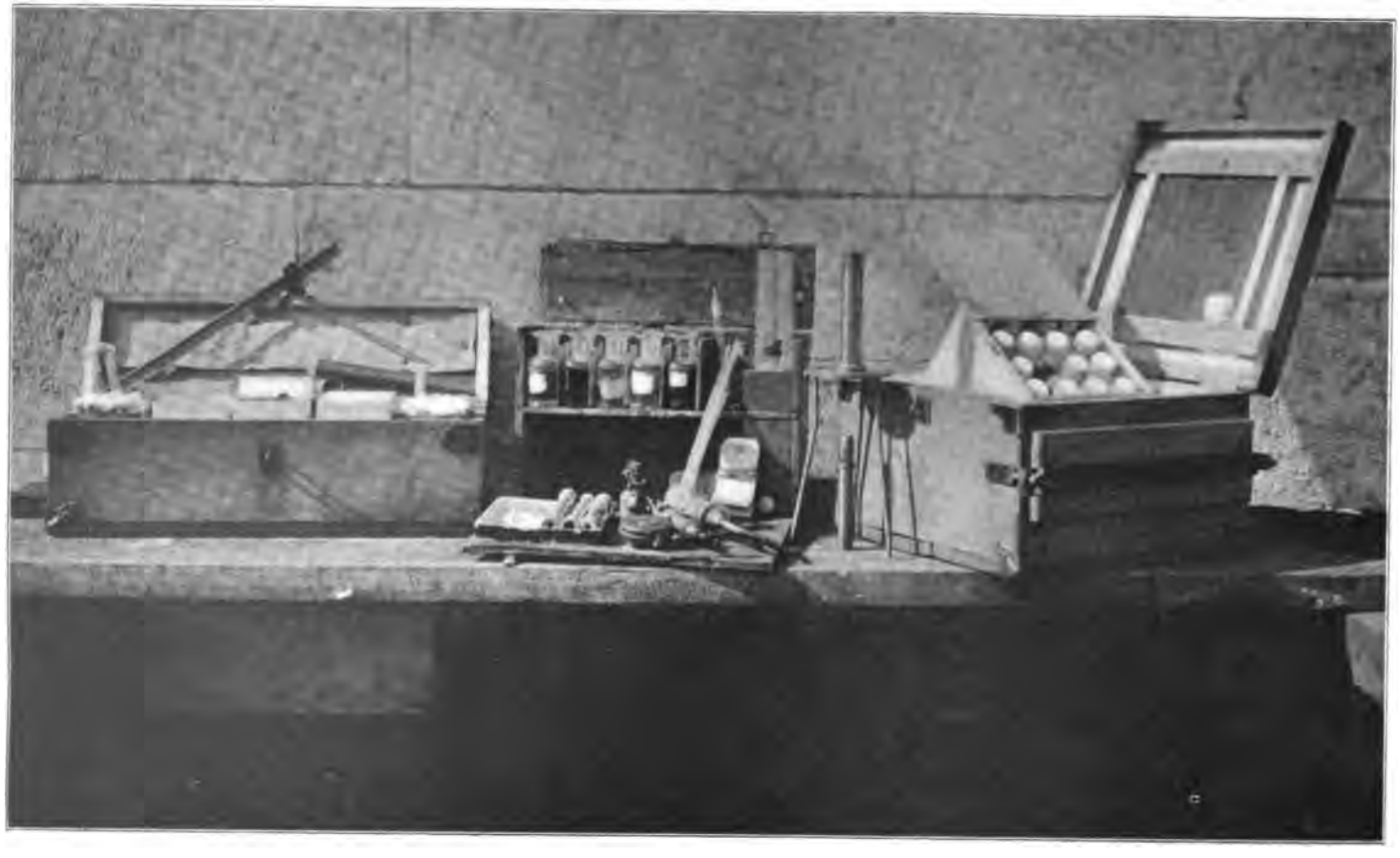
Chemical Analyses. Chemical analyses were made in accordance with the report of the Committee on Standard Methods of Water Analyses. The determinations of turbidity were made with a candle turbidimeter when the turbidity of the sample was above 50 parts per million and with the U. S. G. S. turbidity rod when below 50 parts per million. For the determinations of dissolved color a U. S. G. S. field outfit was used. All samples containing visible suspended matter were first filtered through a Berkefeld filter. The alkalinity determinations were made with N 50 sulphuric acid, using methyl orange as an indicator. During the first examinations erythrosine was used as indicator as recommended in the report of the Committee on Standard Methods, but in the spring of 1907, during examinations at Youngstown and Warren (Pages 275 and 293) it was found that neither indicator was of value as showing the presence of small quantities of alum in the water until at least 24 hours after the alum had been applied. Both indicators give the same results and as methyl orange is more convenient it has subsequently been used. The determinations of phenol alkalinity and free carbonic acid were made in the 9-inch tubes belonging to the candle turbidimeter. These latter determinations were of particular value in connection with the treatment of water with copperas and lime, and were made on the majority of the samples collected at those plants where this process of coagulation is used.

Analyses of Coagulants. One important feature of the examinations of the plants, particularly those using alum, has been the investigation of the cost and quality of the coagulant. The samples of alum were analyzed in the laboratory, and their alumina content and basicity determined. When the analyses showed the alum to be of unsatisfactory quality, the officials were so notified, and they were advised where a better grade might be obtained, frequently at a less cost.

The method used for analyzing the alum was that described in the Journal of The American Chemical Society, (Vol 24, Page 457), and has proven very satisfactory. The results of the analyses are shown in the summary at the conclusion of this report, (Page 311).

DAILY RECORDS AT PLANTS.

At four of the plants examined there are well equipped laboratories, and at three of the plants daily analyses of the raw and treated water are made by competent chemists. At such plants there are kept daily records of the analyses made and of data showing the important operating features, such as daily water consumption, quantity of coagulants applied and amount of wash water used. At those plants where there were no analytical data available, at the request of the Board, daily records have been kept showing the important operating features and in some instances the turbidity of the raw water. Monthly averages of these daily records, where available, have been included in the special report of each plant. While this method of presenting the analytical data may be crit-



Field Apparatus.

icised as not showing the daily variations in the results obtained, it is not practicable to include in this report the results of the daily determinations, nor is it thought that a single or perhaps two determinations are sufficient to indicate the average results obtained during a day's run. The hourly variations in the character of the raw and treated water are frequently so great that several analyses are necessary daily to determine their average contents.

SAMPLING KIT.

The field outfit used during the examinations comprised four parts, chemical apparatus, apparatus for obtaining bacterial counts, containers for transporting B. coli samples, and containers for transporting samples for chemical determinations in the laboratory.

Chemical Outfit.

For transporting the chemical apparatus there was used a U. S. G. S. traveling case, described in Paper No. 151 of the U. S. G. S. Water Supply and Irrigation Papers. This case contained the following apparatus:

A U. S. G. S. color outfit containing also apparatus for determining turbidity.
Candle turbidimeter.
Alcohol lamp.
4-ounce dropping bottles containing:
- N 50 sulphuric acid.
- Erythrosine.
- Methyl orange.
- Chloroform.
- N 22 sodium carbonate.
- Standard alum solution.

One 16-ounce bottle containing alcohol.
Two tubes for candle turbidimeter.
Two, 10 c. c. burettes.

Bacterial Outfit.

The bacterial outfit comprised boxes for the collection of samples and their shipment to the laboratory, and also the necessary apparatus for plating the samples in determining bacterial counts.

The coli boxes each contain sixteen 4-ounce glass stoppered bottles. In arranging for their transportation it was necessary that the shipping boxes contain ice, and that there should be no possible contamination of the samples. The shipping boxes were 17 inches square by 11 inches deep and opened at the top. They contained an air chamber ½ inch wide all the way around except at the top, and inside the air chamber was another compartment 4 inches wide for holding the ice, which was introduced through an opening in the side. This ice chamber was water tight and was formed by the metal lining of the air chamber and by a separate box fitted into the center of the shipping box and supported at the bottom. Into this central box was placed another covered metal box containing the sample bottles. This container was 9 inches square and was divided into sixteen compartments for holding the bottles. To prevent rattling during transportation, a strip of heavy felt was placed on the cover of the shipping box containing the samples.

It will thus be seen that the shipping boxes were in two parts, the one a container of the samples, and the other an ice box, and as the latter was separate and water tight, there was no possible contamination of the samples due

to leakage during transportation. The boxes held approximately 50 pounds of ice, a quantity usually sufficient to keep the samples cold for 24 hours, and in general it may be said that they have proven very satisfactory, and that their only criticism has been in regard to excessive weight, which makes them somewhat inconvenient for transportation.

The boxes containing the plating outfit were designed to provide sufficient apparatus for plating 15 samples in duplicate. They were 8 inches wide by 25.5 inches long by 9 inches deep. For transporting the plates there were provided small paste-board boxes about 4 inches square, each holding two plates. Each shipping box held 15 of these small paste-board boxes, or 30 plates in all, contained in three compartments during transportation. For the media, there were provided small wooden boxes of the same cross-section as the paste-board boxes, and of the same depth as the shipping box. Each of these small boxes held approximately 40 test tubes of the size used, and they were carried in two compartments of the same size as those holding the small paste-board boxes.

It will thus be seen that the shipping boxes contained five compartments, in two of which were carried the media and in the other three the plates. In another compartment about 1½ inches wide, extending the entire length of the box, there were carried pipettes contained in metallic boxes, each of which held approximately 12 pipettes. This compartment also proved very useful in transporting miscellaneous small articles.

The shipping boxes opened at the top and in order to prevent breakage, a strip of harness felt was provided in both the top and bottom of the box, and these, together with the fact that the plates were contained in paste-board boxes, proved very efficient in preventing breakage. In general it may be said that but very few plates were broken in transportation, and the few counts lost were due to slippage of the media.

Chemical Sampling Bottles.

It was occasionally necessary to ship a few samples to the laboratory for determinations impracticable to complete in the field, and for this purpose there were used one-quart glass stoppered bottles, which were shipped in wooden boxes. These boxes each held four bottles and were lined with carpet to prevent breakage.

CO-OPERATION OF OFFICIALS.

As stated in the chief engineer's report, it was the purpose of these investigations, not only to determine the actual results obtained at the various plants, but also to interest the local officials in the work, and to get them if possible to co-operate with the Board in obtaining the best results. In general it should be said that there has been a ready response, particularly on the part of the waterworks superintendents, who have very kindly assisted both during the examinations and in the furnishing of records and cost data. When it has been found that a change in operation would probably produce better results, such changes have been recommended either informally during the examination, or subsequently in a letter from the secretary of the Board, and these recommendations have generally been very gladly carried out by those in charge of the plants.

GENERAL ARRANGEMENT OF DETAILED REPORTS.

For convenience, the detailed reports have been arranged in alphabetical order. The investigation has covered the examination of twenty plants, among

which are included seventeen of mechanical filtration, one of slow sand filtration at Fostoria, one of natural infiltration on the Ohio River at Gallipolis, and one filter crib on Lake Erie at Linwood Park. Of the seventeen mechanical filter plants examined, eleven use alum as a coagulant and six copperas and lime, as shown in the following table:

MECHANICAL FILTRATION PLANTS IN OHIO.

PLANTS USING ALUM.	PLANTS USING COPPERAS AND LIME.
Batavia,	Cincinnati,
Bucyrus,	Elyria,
Conneaut,	Lorain (2),
Dennison,	Marietta,
Geneva,	Vermilion.
Newark,	
Pomeroy,	
Rocky River,	
Upper Sandusky,	
Warren,	
Youngstown.	

Of the twenty purification plants, eleven are owned by the municipality and nine by private interests, as shown below.

WATER PURIFICATION PLANTS IN OHIO.

MUNICIPAL PLANTS.	PRIVATE PLANTS.
Batavia,	Bucyrus,
Cincinnati,	Conneaut,
Elyria,	Dennison,
Fostoria,	Linwood Park,
Gallipolis,	Newark,
Geneva,	Pomeroy,
Lorain (2),	Rocky River,
Marietta,	Upper Sandusky,
Vermillion.	Warren.
Youngstown.	

Except in a few instances the detailed reports which follow have been compiled as outlined at the beginning of the introduction, and it has been the intention to use the same general arrangement for all the reports whenever possible.

BATAVIA.

The village of Batavia is in Clermont County, in the southwestern part of Ohio near Cincinnati. It is in the center of a farming district, and its only industry is a brick and tile plant. In 1906 its population was estimated at 1,100.

HISTORICAL.

The waterworks were built by the village of Batavia in the fall of 1900. The pumping plant is located about one mile above the village, on the east branch of the Little Miami River, from which the supply is taken.

Above Batavia the watershed of the east branch of the Little Miami consists of a long, narrow strip of territory, on which is a large number of farms gathered into numerous small communities, none of which have municipal water supplies or sewers. The total population of these communities is 3,400. The lands along the river valley have generally steep cultivated slopes, and as the stream has an average fall of 10.5 feet per mile, its flow is rapid and the water generally contains considerable suspended matter.

Williamsburg, with a population of 1,000, is the nearest community of any size on the watershed, and it is 19 miles above the intake of the Batavia waterworks. There is no direct pollution at this point other than the usual amount of surface wash into the river. At Lynchburg, 42 miles above, with a population of 907, there is a large distillery, which has, until 1906, discharged its waste directly into the stream, so that the river has constituted a nuisance until 1906, when, at the recommendation of the State Board of Health, a plant was installed for the purification of the distillery wastes. Moreover, until 1906 some one thousand steers were kept near the distillery during the winter and fed slop. They were housed in small pens, from which the drainage was at times all run directly into the creek.

On account of the constant danger of pollution from the above sources, and also because of the undesirableness of the river for domestic uses due to the large quantities of suspended and organic matter contained, the river was approved by the State Board of Health as a source of supply for Batavia, only after purification.

DESCRIPTION OF PLANT.*

The works installed comprise the following general features: a cast iron intake in the river; low and high service pumps; coagulating or settling tanks; a gravity mechanical filter; a clear well; a reservoir; and a distributing system.

Intake and Raw Water Pumps.

The intake consists of a 6-inch cast iron pipe, laid directly on the bottom of the river. It is connected to the suction of the raw water pumps, which are two horizontal duplex McGowan pumps of 500,000 gallons capacity each. Their discharge pipe is of 4-inch cast iron, and the total lift to the top of the settling tanks is about 40 feet.

Coagulating System.

Coagulant. The coagulant used is aluminum sulphate obtained from the Jerecki Chemical Company of Cincinnati, Ohio.

Solution Tanks. The tanks for dissolving and storing the coagulant are in the filter room and comprise two wooden tubs, each 3.5 feet in diameter by 5.5 feet deep with a capacity of 470 gallons.

Method of Application. From the tanks the solution flows through a 1-inch brass pipe, and enters the suction near the raw water pumps. The only means of control of the flow is a globe valve near the tanks.

Coagulating Basins. The coagulating basins are located on rising ground back of the pumping station, and comprise two wooden tubs, each 20 feet in diameter, with an available depth of 13 feet, and a capacity of 30,000 gallons each. The length of the storage period depends on the method of operation, and it is the custom to use the tanks in series, and to allow the greatest possible period of sedimentation in the tanks. The coagulating period ranges from 8 to 48 hours, and is generally about 20 hours. The inlets to the basins are carried up-

*See Plate I.

ward through the bottom and terminate just below the surface of the water. Flat pans are attached immediately below the top of the risers for the purpose of aeration. The outlets are floating tubes, by which the discharge is maintained at a constant depth of approximately 2 feet below the surface of the water in the tanks. In the winter considerable trouble has been experienced from ice, and it has been found impracticable to keep in repair the chains by which the floats are attached to the outlet tubes.

Automatic devices, by means of which the supply to each tank was cut off when full and the other turned on, were originally installed, but have been found impracticable. The bottoms of the basins are practically on a level with the top of the filter to which the water flows by gravity.

Filter.

The filter is a wooden tank, 8 feet in diameter, with an area of 50.3 square feet. At 100,000,000 gallons per acre per day its capacity is 120,000 gallons in 24 hours.

The filter contains a false bottom of 2-inch wooden planks, 8 inches above the bottom, and into this false bottom are fastened at 6-inch intervals the individual brass strainers, composing the collecting system. The filtering material comprises a 6-inch layer of gravel screened through a 1-inch screen and over a ½-inch screen, and a layer of sand, 3½ feet deep with an effective size of .46 m. m. and a uniformity coefficient of 1.3. The filter is washed by a reverse current of water obtained directly from the mains, and the dirty water is carried away through an annular metallic trough 6¾ inches wide by 9⅜ inches deep. To assist in washing there is provided a system of rakes composed of steel rods extending about 22 inches into the sand. No loss of head gauges are furnished, but the rate of operation of the filter is governed by a controller, which consists of a butterfly valve, operated by a float in a small open wooden tank. All of the connections to the filter are composed of 4-inch wrought iron pipe.

Storage of Filtered Water.

Clear Well. The clear well for the storage of filtered water is 36 feet south of the pump house, and consists of an uncovered circular basin with brick walls and a concrete bottom. It is 43 feet in diameter, with an available depth of 16 feet, and has a capacity of 174,000 gallons. The well should be roofed, as the sides and bottom are generally covered with a luxuriant growth of fresh water sponge, especially during the summer season.

High Service Pumps. From the clear well the water is pumped to the reservoir by two, horizontal, duplex McGowan pumps, each of 750,000 gallons capacity, which act against a pressure of from 90 to 95 pounds per square inch.

Distributing Reservoir. The distribution reservoir for the storage of filtered water is on a hill in the eastern part of the town and is a covered basin with brick walls and a concrete bottom. It is 30 feet in diameter and 17 feet deep, with a capacity of 98,000 gallons. Previous to the summer of 1906, the reservoir was uncovered and much trouble was experienced from luxuriant growths of fresh water sponge, accompanied by musty odors in the water, but these have been removed since the basin was covered.

EXAMINATIONS.

Four examinations of the Batavia plant have been made as follows: July (13-16), December (26-27), 1906; May 20th and August (30-31), 1907.

OPERATION.

The water and light plants are contained in the same building and the operation of both plants has been conducted by one engineer, who generally is on service from about 2:00 o'clock in the afternoon until midnight. The operation of the water plant has been made to coincide with that for the lights, although probably better results might be obtained if more attention were paid to the operation of the water plant.

The general method of operation during the summer is briefly stated as follows: During the afternoon filtered water is pumped to the reservoir and unpurified river water to the storage tank of the N. & W. Railroad, one of the largest consumers at Batavia. When their tank has been filled, water is then pumped to the settling basins, receiving the coagulant on the way, and is run through the filter on the following day, either in the afternoon or evening. In the winter it is necessary to operate the lights in the early morning, and the superintendent generally runs the light plant from 4:00 o'clock to 7:30, at which time he also operates the filter, using the water which has been pumped to the tanks the previous evening.

As the methods of operating the plant are so intimately related to the results obtained, it is considered desirable to describe them in connection with the discussion of each examination.

Average Daily Consumption.

It has been found impossible to interest the officials at Batavia in the special investigation, and the only records received are for the month of January, 1907, during which time the average daily consumption was about 40,000 gallons. This is approximately the quantity pumped at the several examinations, and it is probable that the average daily consumption for the entire year is not very different from the above figures.

Application of Coagulant.

The coagulant charges are introduced into a small perforated box in the top of the storage tanks. Water is then passed through this box into the tank below where the resulting solution is stored until used. It is then conveyed by gravity into the raw water suction. The quantity of coagulant used is varied with the judgment of the engineer and is generally unnecessarily large. Usually about 10 pounds are applied to the contents of one settling tank, but occasionally this is increased to 20 or even 30 pounds. The use of such large quantities causes an undue increase in the incrustants of the filtered water, but there is always sufficient alkalinity present in the river water to insure the neutralization and removal of the alum.

Coagulating Tanks.

It is probable that when installed it was intended to use the coagulating tanks on the "fill-and-draw" method and to allow the maximum possible period of sedimentation in the tanks. The floating outlets were provided so that the water may always be taken from the top of the tanks, but during cold weather considerable trouble has been experienced with ice and the chains connecting the tubes and floats were broken during the winter of 1906. These have not been repaired during the special investigation, and instead of applying to the filter the clarified water from the top of the tanks, water has been taken from near the bottom.

FILTER.

From the fact that the operation of the water plant has been made to conform to that of the light plant, it has generally been the custom to run the water through the filter from the settling tank as rapidly as possible on which account the valve beyond the controller has been wide open and the filter has operated at its maximum possible rate. During the first three examinations the time necessary to run the contents of one of the settling tanks to the filter immediately after washing was about 3 hours, and the average rate of filtration was about 160,000,000 gallons per acre per day. This rate was unusually high, especially considering that there was no coagulation visible in the applied water. Following the recommendations of the State Board of Health, the rate of filtration was somewhat decreased after the third examination, but it has still been too great to give satisfactory results.

It has been the custom to wash the filter after every other run, that is, after filtering approximately 45,000 gallons of water. The wash water is applied at rates varying from 8 to 18 inches per minute, according to the degree of opening of the supply valve, but the average rate is about 14 inches per minute for 8 minutes, giving 9.3 vertical feet per wash, corresponding to 3,500 gallons. It has generally been found that too long a period is allowed to lapse between washings, as the filter runs at a very much decreased rate toward the end of the second run; also it was noted on the examination of August 30th, 1907, that the sand at the center of the filter was imperfectly washed and was covered with a layer of mud about 2 inches thick. This deposit was probably due to two factors, that the mechanical rakes do not give a good agitation in the center of the tank, and that, as sand had leaked through the strainer system, the gutters were about 18 inches above the surface of the filtering material, a distance which was too great to give a satisfactory removal of the heavier suspended matters with the usual rate of application of the wash water.

Subsequent to the examination of August 30th, 1907, the superintendent was advised by the Board that the surface of the sand should be scraped and cleaned and that at least one foot more of filtering material should be placed in the filter.

CHARACTER OF RAW WATER.

The four examinations made at the Batavia plant have covered nearly all the conditions of the river water, which is very largely influenced by the prevailing weather conditions. The examination of July 11th, 1906, followed a very heavy rain storm, which caused a very rapid rise in the river, and it was stated by the engineer that the water then was in as bad a condition as he had ever seen it. From the analyses it will be seen to have contained large quantities of suspended matter; it will be noted also that, although its bacterial content was high it contained no coli. It is probable that the alkalinity at this time was as low as is ever reached except under abnormal conditions and it is apparent that the river water will always neutralize the maximum amount of coagulant that it is necessary to apply for its purification.

On December 26, 1906, the river was frozen over and the water contained very little suspended matter, but it will be seen that the number of bacteria contained was high and that coli were present, indicating recent pollution. The water also contained considerable dissolved color, especially considering the season of the year.

On May 20th and August 30th, 1907, very similar weather conditions prevailed as both examinations followed a heavy rain storm of the previous day

On May 20th the river was rising and the alkalinity was decreasing, a fact which, together with the increase in the number of bacteria contained, would indicate that the crest of the rise in the river had not been reached. Coli were found at both examinations and are significant as showing that the pollution of the river is more marked during low than during high stages of the river.

From the evidence obtained at the several examinations, it appears that the character of the water of the east branch of the Miami at Batavia varies considerably with the weather conditions; that it frequently contains large quantities of suspended matter and considerable numbers of bacteria, which, together with the presence of coli, indicate a considerable pollution of the river. The evidence indicates that the water is entirely unfit for use without purification.

EFFICIENCIES.

Guarantee by Filter Company.

The contract given by the filter company when the plant was installed contained the guarantee that the filtered water shall be clear and free from suspended matters; also that when the number of bacteria in the raw water is less than 7000 per c. c., the effluent from the filter shall not contain more than 200 per c. c.; when the raw water contains more than 7,000 per c. c. there shall be a removal by the filter of at least 97 per cent.

Application of Coagulant.

The means for applying the alum solution have not been very satisfactory, as the rate at which it enters the suction is indeterminate and the only means provided for its regulation is the small globe valve in the solution pipe. They could undoubtedly be much improved by providing a ball-cock tank which would admit of a constant pressure on the regulating valve and a much more constant application of the solution. Although the rate at which the solution is applied sometimes varies considerably during the time required to fill one settling tank, there is such a long period of storage in the latter that they serve as equalizers, and the fluctuations in the application of the coagulant probably have no appreciable effect on the results obtained by the plant.

Coagulating Basins.

In order to determine the degree of purification accomplished by the basins, samples were taken of the applied water from the top of the filter during each examination. Their analyses indicate that the results obtained have varied with the length of time allowed for the coagulation, and with the quantity of alum used. On July 11th, 1906, the water which was applied to the filter during the evening had been pumped to the basin on the afternoon of the same day, and the average period allowed for coagulation was only about 5 hours. The amount of coagulant used, about 8 grains per gallon, was very large, to which fact is to be attributed the satisfactory removals obtained during this first run. The water which was applied to the filter on July 12th had been pumped on the evening of July 11th and the satisfactory results obtained were also undoubtedly due to the large amount of alum used. On December 26-27, 1906, the period of coagulation allowed was about 20 hours, and about 3 grains of alum per gallon were used. The water applied to the filters contained very little suspended matter but considerable numbers of bacteria. On May 20th, 1907, the water which was filtered had been pumped on the previous evening, and although the water applied to the filter con-

tained 2,300 bacteria per c. c., that at the top of the settling basin contained but 225 per c. c. The results of August 30th are very similar to those at this examination.

The evidence obtained from these examinations shows that during but two of the several runs has the plant given satisfactory results, namely, with about 8 grains of coagulant per gallon and 5 hours sedimentation, and 3 grains with 48 hours sedimentation. It is apparent that with the usual period (20 hours) allowed for the coagulation of the water, there is too great a deposition of the coagulated masses in the water in the settling tanks to give suitable preparation for filtration, also that this period is too short to give a satisfactory degree of purification by the coagulating basins alone. The fact that water is taken from the bottom of the settling tanks and not from the top has contributed largely to the poor results obtained.

Filter.

During all of the examinations the percentage removal of bacteria from the applied water by the filter has been unusually low. This may be accounted for by the fact that the water has not been suitably prepared for filtration, as discussed above, and also that the filter has been operated at too great a rate, especially considering the character of the applied water. Following each of the several examinations the waterworks officials have been advised by the Board to decrease the rate of filtration, but the changes made have not been sufficient to improve the character of the results obtained. The fact that the filter has not been properly washed and has not contained sufficient filtering material has also contributed to the poor results obtained.

REVIEW OF EFFICIENCY OF PLANT DURING SPECIAL INVESTIGATIONS.

From the evidence obtained during the several examinations, it is apparent that at no time has the Batavia plant been giving satisfactory results and it is evident also that the raw water is of such a character that the filtered water frequently contains evidence of pollution and would not be considered a potable supply. The poor efficiencies obtained are partly due to the general lack of attention on the part of the officials who apparently do not appreciate the necessity for careful management of the plant. As the outlets to the settling basins have not been in repair during the investigations, and as the filter has generally been run at too great a rate, it is not possible at the present time to come to a definite conclusion as to what results may be obtained when the plant is operated in the best possible manner. It is apparent, however, that one of the principal causes for poor results has been the improper use of the coagulating basins. This fact has been called to the attention of the Batavia officials and changes in the method of operating the plant have been suggested without result.

No satisfactory records are kept of the Batavia plant, and it has been impossible to obtain estimates either of the cost of its operation or of its construction. These would, however, be of doubtful value from the fact that the operation and construction of the water plant are combined with those of the municipal lighting plant.

TABLE NO. 1.

Batavia — Results of Analyses During Examinations.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	
	1906	P. M.								
167	7-11	4:30	Raw water (river).....	7,000	0	0	16	600	75	.....
172	7-11	9:00	Raw water (river).....	18,000	.....	.....	12	.....	79	.....
171	7-11	8:35	On filter (1).....	400	.....	.....	.....	.....	.....	.....
174	7-11	11:30	On filter (1).....	1,100	0	0	.....	.....	.....	.....
168	7-11	4:30	Effluent	135	0	0	0	0	23	.....
170	7-11	8:30	Effluent	80	.....	.....	0	.....	18	.....
173	7-11	9:30	Effluent	48	0	0	.....	.....	.....	.....
175	7-11	11:30	Effluent	325	0	0	0	0	14.5	.....
169	7-11	5:30	Tap in force main.....	80	.....	.....	0	.....	.....	.....
		A. M.								
176	7-12	7:15	On filter (2).....	600	.....	.....	.....	.....	.....	.....
179	7-12	8:45	On filter (2).....	125	.....	.....	.....	.....	.....	.....
177	7-12	7:20	Effluent	375	.....	.....	0	0	39	.....
178	7-12	8:30	Effluent	150	0	0	.....	.....	.....	.....
180	7-12	9:45	Effluent	200	0	0	0	0	37	.....
		P. M.								
886	12-26	4:45	Raw water from river.....	11,000	0	0	30	30±	146	.....
892	12-26	9:00	Raw water from pump.....	3,300	+	+	30	30±	147	.....
888	12-26	5:00	On filter (3).....	1,300	.....	.....	15	10±	117	.....
891	12-26	7:30	On filter (3).....	1,400	.....	.....	.....	10±	116	.....
893	12-26	9:15	On filter (3).....	1,200	.....	.....	10	10±	116	.....
890	12-26	7:30	Filter effluent	1,300	0	0	10	<5	116	.....
894	12-26	9:30	Filter effluent	1,000	0	0	10	<5	117	.....
		P. M.								
887	12-26	5:00	Tap in force main.....	1,300	0	0	15	<5	78	.....
889	12-26	7:00	Tap in stable Hamilton hotel.	700	0	0	15	<5	80	.....
		A. M.								
895	12-27	10:30	On filter (4).....	8,000	.....	.....	.....	.....	126	.....
		P. M.								
898	12-27	12:30	On filter (4).....	3,900	.....	.....	10	.....	124	.....
		A. M.								
896	12-27	10:30	Filter effluent	2,000	0	0	15	5±	125	.....
		P. M.								
899	12-27	12:30	Filter effluent	950	0	0	10	<5	123	.....
		M.								
897	12-27	12:00	Tap in stable Hamilton hotel.	900	0	0	10	<5	68	.....

(1) Pumped during afternoon of July 11th. (2) Pumped during evening of July 11th. (3) Pumped during evening of December 25th. Sample No. 886 — Temp. 3 degrees, C. (4) Pumped during evening of Dec. 26th.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	CO_2
	1907	P. M.								
1321	5-20	3:00	Raw water from river.....	2,000	0	+	30	160	121	2
1326	5-20	7:30	Raw water from river.....	6,000	0	+	.....	170	114	.....
1324	5-20	5:45	Top of settling basin (1)....	225	0	0	.....	25	61	12
1327	5-20	8:	Top of filter	2,350	0	+	.....	.....	61	12

TABLE NO. 1 — Concluded.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	CO_2
1823	5-20	5:40	Filter effluent (2).....	170	0	0	.....	5±	120	.....
1825	5-20	7:15	Filter effluent (1).....	1,350	0	+	10	<5	66	.....
1828	5-20	8:15	Filter effluent (1).....	1,380	0	+	8	<5	62	10
1829	5-20	9:15	Filter effluent (1).....	1,500	0	+	8	<5	62	.....
1822	5-20	8:00	Tap in force main.....	330	0	+	10	<5	161	4
1830	5-21	A. M. 7:00	Tap in stable Hamilton hotel	290	0	+	12	<5	151	.....

(1) Pumped during evening of May 19th.
(2) Pumped during evening of May 18th.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	CO_2
1585	1907 8-30	P. M. 5:00	Raw water from pump.....	1,200	+	+	20	150	124	3.5 Ph. Alk.
1586	8-30	5:00	Top of settling basin (1)....	300	0	0	.....	20	108	5
1587	8-30	8:30	On filter (1).....	400	0	0	.....	30±	108	5
1588	8-30	8:30	Filter effluent	200	+	+	8	<5	109	4.5
1590	8-30	10:00	Filter effluent	375	0	+	8	<5	109	.....
1589	8-30	9:00	Tap in force main.....	375	0	+	10	<5	104	4.0

(1) Pumped during evening of August 29th.
Iron (Fe) Samp. No. 1585, 0.9; Samp. No. 1586, 0.5; Samp. No. 1588, 0.1; Samp. No. 1589, Trace.
Tot. Hardness, Samp. No. 1585, 135; Samp. No. 1586, 127; Samp. No. 1588, 131; Samp. No. 1589, 139.

BUCYRUS.

The city of Bucyrus is in the north central part of Ohio, in Crawford County, on the Sandusky River. Its population is estimated at 6,600. It is the center of a farming district, and while essentially a residential town, contains a considerable number of small general manufacturies.

HISTORICAL.

The various installations that have been made at Bucyrus in the effort to secure a satisfactory water supply have been largely influenced by a desire to obtain a system that would admit of the least possible cost of operation. Among the several methods tried are included a ground water supply, followed by the use of the Sandusky River at first direct, but subsequently improved by passing through pressure filters; and finally an impounded supply obtained by damming a small tributary to the Sandusky River. It was hoped that the latter would give

water of a satisfactory quality without purification, but it was soon found that filters were necessary to remove the suspended matter. A filter plant was built in 1905, and is in use at present at such times as the water in the reservoir is of an objectionable appearance.

Original Installations.

The waterworks were first built in 1883 by the Bucyrus Development Company, and comprised a shallow dug well on the bank of the Sandusky River, a direct intake to the river, a pumping station and distributing system. The pumping station was located in the extreme northern part of Bucyrus on the Sandusky River, and has been in constant use with but few changes up to the present time. Although it was expected to obtain a sufficient quantity of ground water from the well for ordinary consumption, a 16-inch connection was provided to the river, from which water could be obtained in cases of fire, or other emergencies.

It was soon found necessary to augment the ground water supply with river water and as this was frequently very turbid and also considerably polluted, two Hyatt pressure filters were installed for its purification in 1886. These were old type vertical filters, 10 feet in diameter, and contained 2½ feet of crushed granite and 1½ feet of coke. They were washed by a reverse current of water without mechanical agitation. Although designed to be used with a coagulant, an average of less than one-third grain per gallon of alum was used during 1887 and it was, moreover, necessary to bi-pass the filters in time of fire. Not only did the filters add considerable expense to the operation of the plant on account of the large per cent. of wash water required, but their bacterial efficiency was low, so that although the water furnished had a better appearance than before the filters were installed, it was not suitable for domestic purposes. With the hope of obtaining better water without purification, a new supply was introduced in 1900, for which a storage reservoir was built on a small creek tributary to the Sandusky River and entering it above Bucyrus.

The drainage area of the creek above the storage dam is approximately 2,500 acres, on which is a population of about 275 persons. On account of the flatness of the watershed and its comparatively sparse population, it was believed that the water obtained by impounding the creek would be sufficiently pure without filtration. This supply was approved by the State Board of Health on May 8th, 1900, on the condition that the water be purified in a manner satisfactory to the State Board of Health, whenever in the opinion of that Board such purification should become necessary.

Several complaints were made to the State Board of Health during 1904 on account of the quality of the water furnished to Bucyrus, and in a report of an examination made by the engineer of the Board at that time, it was stated that although there was no serious danger from pollution of the supply, yet the water furnished frequently contained large amounts of suspended matter and for this reason was objectionable. The Board directed that the supply be filtered, as a result of which action the present mechanical filter plant was installed in the fall of 1905.

The filter plant was approved by the State Board of Health on October 25th, 1905, upon the conditions:

"First: That the management and operation of the plant, the use of the coagulant, and the method of controlling the rate of filtration be subject at all times to the approval of the State Board of Health.

Second: That the clear water reservior be so protected that no polluted water, either from the surface of the land or from the ground be allowed to come in contact with the filtered water."

DESCRIPTION OF PRESENT WATERWORKS.

During the special investigation by the State Board of Health, the water purification plant of the Bucyrus Development Company comprised the following features: An impounding reservoir; a wooden pipe line two miles long; a coagulating basin; two gravity mechanical filters; a clear well for which the old dug well built in 1883 is used, and a pumping plant which is essentially the same as was originally installed.

Emergency Supply.

As has been previously stated, when the waterworks were first constructed an emergency intake was provided by which the water from the Sandusky River could be taken directly into the old well without purification. As it is probable that this intake or bi-pass is occasionally used, particularly in times of fire, the following is a statement of the character of the river water:

The Sandusky River has a drainage area of 94 square miles above Bucyrus. The nearest community of any size is 16 miles above the waterworks at Crestline with a population of 3,300, the drainage from which enters the river direct. Moreover, the land bordering the river is used extensively for pasturage of hogs and cattle. In general it may be said that the river water is of an unattractive appearance and is always subject to pollution from the sewage of Crestline and the drainage from the pasture lands through which it flows.

Impounding Reservoir.

The source from which the water supply for Bucyrus is generally obtained is the impounding reservoir formed by a storage dam on a small creek tributary to the Sandusky River. The dam by which the water is impounded has a top width of 38 feet and side slopes of 2 to 1. A concrete weir is provided, 60 feet long, and designed to take care of the overflow from the reservoir with a maximum depth of flow of one foot. The area actually flooded is about 60 acres and the total storage is 150,000,000 gallons.

A circular concrete gate house or intake is provided at the beginning of the pipe line, and by means of a series of ten 8-inch pipes, 2.2 feet center to center, it is possible to take water from any desired level. The flow line of the reservoir is 26.4 feet higher than the floor of the pumping station, and the water is carried by gravity through a 14-inch wooden pipe, two miles long and discharged into the coagulating basin.

Coagulating System.

Coagulant. The coagulant used at Bucyrus is the Regal brand of aluminum sulphate obtained from the General Chemical Company of Chicago.

Solution Tanks. The alum is dissolved and stored in two small tanks, each 4 feet in diameter by 4 feet high, holding 375 gallons, and placed under the roof of the coagulating basin.

Application. The solution of the coagulant is conveyed by gravity through a small pipe to the inlet of the coagulating tank. The only means of control of its rate of application is a small globe valve in the solution pipes near the tanks.

Coagulating Basins. The basin for preliminary treatment of the water consists of a wooden tank with an average diameter of 23 feet and depth of 15 feet, holding 46,500 gallons. It is well baffled with six radial vertical partitions, and the theoretical length of the coagulating period is 1½ hours. As the distance traveled in the tank is approximately 60 feet, the average velocity of the water is 0.9 foot per minute.

The inlet consists of a 10-inch cast iron pipe, 18 inches above the bottom of the tank in the side, while the outlet is also of 10-inch cast iron, 2 feet below the top of the tank. A float valve is provided on the inlet to prevent the overflow of the water in the tank.

The top of the settling tank is approximately 10 feet above the tops of the filters to which the coagulated water flows by gravity, and the depth of water carried on the filters is regulated by butterfly valves and floats on their inlets.

Filters.

Capacity of Plant. The filter plant has a guaranteed capacity of 1,000,000 gallons in 24 hours and comprises two wooden tanks each 14 feet in diameter at the top and 15 feet in diameter at the bottom, with an effective sand area of 165 square feet in each filter, equivalent to .00379 acre. In order to furnish the quantity of water guaranteed, allowing two hours out of service per day, the necessary average rate of filtration must be 144,000,000 gallons per acre per day. At 125,000,000 gallons per acre per day, they would furnish but 868,000 gallons in 22 hours or 948,000 gallons in 24 hours.

Strainer System. The strainer systems comprise manifolds of 1.5-inch slotted brass pipes, averaging about 2 feet long and connected to main rectangular manifolds of cast iron pipe 6 inches square. The lower portions of the laterals are imbedded in concrete and their upper surfaces are perforated with narrow slits.

Filtering Material. The filtering material consists of 3.0 feet of Mississippi River sand, and has an effective size of 0.42 m. m. and a uniformity coefficient of 1.6. It originally contained too large an amount of fine material, which was removed by scraping the surface of the sand in the filters after washing.

Washing System. There are two possible methods of washing the filters, by one of which, unfiltered water from the reservoir is applied by gravity, while with the other, filtered water is pumped from the clear well, using one of the old pumps originally installed. An annular trough, 4 inches wide by 12 inches deep, of wrought iron plates is built around the inside of each filter tub for the removal of the dirty wash water.

It will be noted from the drawings of the filters, shown on Plate II that mechanical agitators consisting of iron rods extending 27 inches into the sand are provided to assist in washing the filters.

Automatic Devices. No loss of head gages are provided, nor any automatic rate controllers, but the effluent pipes are reduced to 4 inches in diameter at the point where they discharge into the conduit leading to the clear well. It was thought that by this means it would be impossible to operate the filters at too great a rate. The filtered water flows to the clear well through a tile pipe and although its joints are cemented, there is a possibility of contamination of the effluent from the plant at this point.

Clear Well.

The only storage of filtered water provided is in the clear well, for which the old dug well constructed in 1883 is used without change. Under the original conditions of approval by the State Board of Health, it was required that this well be made water tight, which has not been done, and at the present time there is a danger of polluting the water in the clear well by the entrance of unpurified surface waters. The well is about 50 feet in diameter, with a storage capacity of 14,500 gallons per foot depth. Although its total depth is 15 feet, the suction of the pump is 4 feet above the bottom of the well, so that the effective depth is but 11 feet, and the total available storage, 160,000 gallons.

The clear well is covered with a conical roof, and no trouble from growths has ever been experienced.

Pumps.

The water is pumped from the clear well directly into the mains by a compound crank and fly wheel Wallace pump, which has a capacity of 35 gallons per revolution and 1,000,000 gallons per day. The pressure generally maintained is 45 pounds per square inch, which is increased in time of fire. Both this pump and that used to wash the filters have two suctions, by which water may be taken, either from the river or from the clear well. No provision is made whereby in case the reservoir becomes empty during the dry season, river water may be supplied to the filters, and at any such time, it will be necessary to pump unpurified river water into the mains.

EXAMINATIONS.

During the special investigation by the State Board of Health, the plant of the Bucyrus Water Company has been visited three times, on January 30th, February (18-20), and December 11th, 1907. On January 30th, 1907, the construction of the plant had not been completed and as the water in the river was clearer than that in the resevoir, the former was being used as a source of supply. On February (18-20) a detailed examination of the plant was made and such samples taken as were necessary to determine the efficiency of the plant. On December 11th, the plant was inspected by the assistant engineer of the Board and it was then found that the filters were not in use as the waterworks officials thought that the water in the reservoir was satisfactory without purification.

OPERATION.

As no storage is provided for filtered water other than in the clear well, it is necessary to operate the plant 24 hours, and two engineers are employed, each of whom has a twelve-hour run. No records are available showing the operation of the plant for 1906 and 1907. On February 19th, 1907, 623,000 gallons were pumped in 24 hours, and it is probable that the present average daily consumption is not very different from this figure.

When the filter plant is in service, the water flows by gravity from the reservoir into the coagulating basin, thence through the filters into the clear well, from which it is pumped directly into the mains. There is no extra attendance required for the operation of the purification plant other than was necessary before it was installed.

Coagulating System.

In preparing the coagulant solutions, the charges of alum are introduced directly into the storage tanks; water is then added and the solution remains in the tanks until needed. Each tank is used in turn and the quantity of solution contained in each is generally sufficient to run about ten hours.

The method of controlling the rate of application of the coagulant is very crude, and, as the storage tanks become emptied, less solution is applied on account of the decreased head on the governing valves. Owing to the small size of the solution piping, it is frequently clogged, and on the night of February 19th no coagulant was applied for over four hours, due to a stoppage in the solution pipe. This is liable to occur at any time when the plant is in operation, as the coagulating features are all out of sight and require frequent inspections by the engineer, which inspections undoubtedly are not made, particularly during the night.

At the examination in February, 1907, it was recommended that, as the method of applying the coagulant was very unsatisfactory, it should be changed and a small pump provided which should force the coagulant solution either directly into the supply to the coagulating basin or into a head tank from which it would flow by gravity into the basin. In either case the storage tanks should be moved into the pump room, and in case the head tank were installed, an overflow from it should be provided into the storage tanks which would insure an agitation of the solution. Either method would permit a much more regular application of the coagulent, and, as it could be much more readily inspected, there would result a better attention on the part of the engineers.

It was also advised at this examination that at least 2½ grains of coagulant per gallon be used at all times.

When inspected on December 11th, it was learned that no change in the method of applying the coagulant solution had been made.

On February 19th, in order to determine the efficiency of the alum used, two sets of samples of water were treated, one with 1 to 4 grains per gallon of Regal alum, such as was used at Bucyrus, and one with 1 to 4 grains of Excelsior alum. It was noted that with the Excelsior alum there was a good coagulation in one hour with two and three grains to the gallon, but that no coagulation started with two grains of the Bucyrus alum until after 1½ hours. After two hours the Excelsior brand gave a much better coagulation with 2 grains than did the Regal alum, a fact which would tend to show that the latter was not as efficient as the Excelsior brand. A subsequent analysis of the alum used at Bucyrus showed that it contained 17.05 per cent. of alumina of which 2.57 was in excess of that required to neutralize the sulphuric acid present. It would appear from the above analysis that the alum used at Bucyrus was of a satisfactory quality, but the results obtained experimentally would indicate that it was not as efficient as the Excelsior brand.

Coagulating Basin.

The water flows from the reservoir by gravity into the coagulating basin, in which a constant depth is maintained by a butterfly valve and float. Some trouble is experienced in the winter from ice, which tends to hold this float in one position,

On account of the considerable difference in elevation between the coagulating basin and the filters, it is necessary to throttle the water applied to the filters and this results in such a great agitation of the applied water that the coagulated masses are broken up. It is impossible to determine whether or not there is a good coagulation in the basin from the appearance of the water on the filter, as no flock is visible on the filter. The applied water has a slight milky appearance, but there is no visible separation of the particles of suspended matter. It is apparent that much better results could be obtained were the coagulating basin more nearly at the same elevation as the filters.

Filters.

Rate of Filtration. In the absence of rate controllers and loss of head gages is has followed that the filters are run at very uneven rates. The clear well is not water tight, and in order to avoid waste the filtered water contained is not allowed to reach a higher elevation than the water in the creek, so that it is necessary to change the rate of filtration to meet the changes in the rate of pumping.

On February 19th, the average rate of pumping was 432 gallons per minute,

or 623,000 gallons in 24 hours. From 7:00 a. m. to 5:00 p. m., however, the average rate of pumping was 510 gallons per minute, during which time the filters were operated at an average rate of 97,000,000 gallons per acre per day.

During the examination there was frequently not more than one foot of storage available in the clear well, and in case of fire the engineer stated that one of the first things necessary would have been to turn raw water into the clear well in order to insure a sufficient supply. At a previous fire it was found necessary to pump 403,000 gallons in 8 hours and 42 minutes, or at an average rate of 773 gallons per minute, and it is apparent that to meet such an emergency there should be maintained at least 5 feet of storage in the clear well,

Washing. During the examination the filters were washed with filtered water pumped from the clear well, and the rate of application varied from 9 to 12 inches per minute depending upon the speed of the pump. The gutters in the filters were flooded when the wash water was applied at a rate greater than 9 inches per minute. The average rate of application was 10 inches per minute for 9 minutes, and the average quantity of water used per wash was 9,300 gallons. In the absence of loss of head gages it is difficult to determine when washing is necessary other than by the appearance of the filter effluents, so that there is a constant danger of running the filters too long between washings. During the examination they were washed at irregular intervals, and the bacterial efficiencies obtained were lower than would have been the case had the filters been washed more frequently. It is probable that under normal conditions the filters should be washed at least twice in 24 hours.

When there is but a small amount of water in the clear well considerable difficulty is experienced in lifting the necessary amount of wash water with the pump, as its valves are considerably worn and there is no foot valve on the suction. This would also suggest the necessity for sealing the clear well and maintaining a greater depth of water in it. On account of the difficulty in applying the filtered water, the operator considered it more desirable to wash the filters with unpurified reservoir water and then to waste the effluent from the filters until it became clear. It is probable, however, that when this method is used there is a considerable contamination of the filtered water.

Subsequent to the examination of February 18th, 1907, it was advised by the State Board of Health that the clear well be sealed to avoid possible pollution, to insure a sufficient storage of water in case of fire, and also to permit the proper washing of the filters. This would also tend to decrease the expense of operating the pumps, as there would result a higher level of water in the clear well and a less lifting by the pumps. It was noted that a considerable increase in the capacity of the clear well would result by lowering the suction of the pump, which was originally kept above the bottom to allow sedimentation in the well when the river water was used as a source of supply. It was also then recommended that rate controllers be provided for each filter, and that, if the closed type were used, loss of head gages should also be provided,

CHARACTER OF RAW WATER.

The evidence obtained on the examination of February, 1907, indicates that the reservoir water then had a comparatively low bacterial content for surface water; also a slight amount of pollution is indicated by the presence of coli in 100 c. c. The water contained sufficient suspended matter to make it unsatisfactory without filtration and chemically it was found to be soft, and to contain a considerable amount of dissolved color. It was of unsatisfactory quality for domestic use without purification.

EFFICIENCIES.

Guarantee.

The contract with the Filter Company contains the guarantee that the filters will furnish "one million gallons of bright, clear, pure water per day of 24 hours, that will pass the State Board of Health, provided this quantity is not exceeded and the filters are washed out when their condition necessitates washing, and the proper amount of coagulant is used."

Coagulating Basin.

Although no samples were taken to show the degree of purification accomplished in the coagulating basin, it was apparent that generally there was a good coagulation maintained in the tank, but that on account of the necessary throttling of the water applied to the filters there resulted a breaking up of the coagulated masses in the applied water, a fact which undoubtedly played an important part in the results obtained by the plant. The efficiency of the coagulating basin was directly influenced by the poor method in use for applying the coagulant, and at times there was no coagulation in the basin, due to the fact that the coagulant pipes had become clogged.

Filters.

During the examination of February, 1907, the effluent from the filters was generally clear, contained but little color, while the absence of coli even in 100 c. c. would indicate that it was potable. The bacterial removal varied considerably, and was not as great as would have obtained if the plant had been properly operated. The efficiency of the filters is directly influenced by the efficiency of the coagulating basin, and as the latter was not properly operated at all times, it had a considerable effect on the character of the filtered water.

A considerably greater number of bacteria were found in the samples of filtered water taken from the clear well than in the effluents from the filters. This would indicate the presence of pollution in the well by the influx of surface or ground waters. It is possible, however, that a less degree of purification had maintained previous to the examination, but the fact that the sample from the mains was similar to the average sample from the well would indicate that there had been no material change in the character of the water pumped.

REVIEW OF EFFICIENCY OF PLANT DURING SPECIAL INVESTIGATION.

The several features that have contributed to the poor quality of the Bucyrus water supply as noted on the examination of February 18th may be summarized as follows:

First. The poor method of applying the coagulant.

Second. The fact that the clear well is not water tight and does not permit of the proper operation of the filters.

Third. The pollution of the water beyond the filters, due either to leakage into the clear well or into the tile pipe by which the effluent from the filters is carried to the well.

Fourth. The absence of rate controllers and loss of head gauges.

At the time of the inspection by the assistant engineer of the State Board of Health, on December 11th, it was learned that none of the several suggestions made by the Board had been followed; moreover, at that time the purification

plant was not in use, as it was considered that the water in the reservoir was of satisfactory quality without purification. While the evidence obtained during this investigation does not indicate any considerable pollution of the water stored in the reservoir, the possibility of its dangerous contamination would require that the Bucyrus supply should always be filtered, even though its appearance is not objectionable, and that all reasonable care should be observed in the operation of the purification plant in order that the best results may be obtained.

TABLE NO. 2.

Bucyrus — Results of Analyses During Examination.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	CO_2
24	1907 2-18	P. M. 4:30	Raw water	1,900	0	+	35	40	60	.....
28	2-19	A. M. 9:00	Raw water	1,800	0	+	30	50	56	2.5
			Average	1,850	.....	.....	32	45	58	2.5
29	2-19	A. M. 10:00	Clear well	720	0	0	8	5±	42	6.0
33	2-19	P. M. 8:00	Clear well	1,800	0	0	5	5±	45	.....
38	2-20	A. M. 9:00	Clear well	1,100	0	+	12	5±	46	.....
			Average	1,200	.....	.....	8	5±	44	6.0
25	2-18	P. M. 4:30	Effluent filter No. 2 (1)	125	0	0	8	<5	40	.....
26	2-19	A. M. 7:30	Effluent filter No. 1	15	0	0	5	<5	39	.....
27	2-19	7:30	Effluent filter No. 2 (2)	360	0	0	5	<5	.....	.....
30	2-19	M. 12:00	Effluent filter No. 1	300	0	0	5	<5	39	.....
31	2-19	12:00	Effluent filter No. 2	90	0	0	3	<5	.....	.....
34	2-19	P. M. 4:00	Effluent filter No. 1	310	0	0	5	<5	41	.....
35	2-19	4:00	Effluent filter No. 2	135	0	+	5	<5	.....	.....
36	2-20	A. M. 9:00	Effluent filter No. 1	160	0	0	5	5±	33	.....
37	2-20	9:00	Effluent filter No. 2	85	0	0	5	5±	.....	.....
			Average	169	.....	.....	5	<5	38	.....
32	2-19	P. M. 1:00	Tap at Hotel Elberson	1,200	0	0	5	5±	44	7.0

(1) No. 1 out of service.
(2) Just before washing.

CINCINNATI.

The city of Cincinnati is in the extreme southwestern part of Ohio, in Hamilton County on the Ohio River. Its population in 1905 was estimated at 340,000. Next to Cleveland it is the largest and most important city in the state, and contains many manufactories and industries of all descriptions.

HISTORICAL.

The waterworks were first installed in 1820 by a private Company, and were bought by the city in 1839 for the sum of $300,000. They comprised a pump house, two pump engines, a reservoir, 19 miles of wooden pipe and 3½ miles of iron pipe.

The city has experienced a very rapid growth, and the districts along the banks of the river have become densely populated for a distance of over four miles above the intake of the waterworks, causing a considerable pollution of the water supply. On this account, and because the water is rarely satisfactory from its physical appearance, the necessity for the purification of the supply has been considered since 1890; moreover, there has been a rapid increase in the demands for a larger supply, and the safe capacity of the pumping machinery and mains has been largely exceeded for a number of years.

A commission of three engineers, appointed in 1896, for the study of the supply, recommended that the use of the Ohio River be continued, but that it be purified by sedimentation and slow sand filtration, A subsequent board of five engineers, appointed in 1897, made exhaustive experimental studies relative to the purification of the Ohio River water, and in a report of these studies by Mr. George W. Fuller in 1898 is stated "That the evidence obtained during these investigations shows that it is practicable to clarify and purify the Ohio river water in a satisfactory manner by using the modified English system (slow sand filtration, preceded by use of coagulant at times), or by the American system (mechanical). Of these two systems, the experience and data indicate clearly that the American system would be the less difficult to operate; would be somewhat cheaper; would give substantially the same satisfactory quality of filtered water; and could be much more readily and cheaply enlarged for future requirements. It is, therefore, considered that the American system of clarification and purification would be the more advantageous to adopt for the local water supply." As a result of these investigations it was decided to install a mechanical filtration plant, for which the water was to be prepared by a long period of sedimentation.

A number of studies have been carried on since the original experimental work in 1899 and have materially assisted in the development of special features embodied in the filtration plant.

The present plant for the purification of the Cincinnati waterworks comprises an intake near the center of the Ohio River, a low service pumping station, two large settling basins, three coagulatin basins, a filter house containing also necessary coagulating apparatus for handling the chemicals, a clear well discharging into a brick tunnel leading to the high service pumping station, and a distributing reservoir. The only part of the old system, the use of which has been continued in the new works installed, is the distributing system including the reservoir at Eden Park.

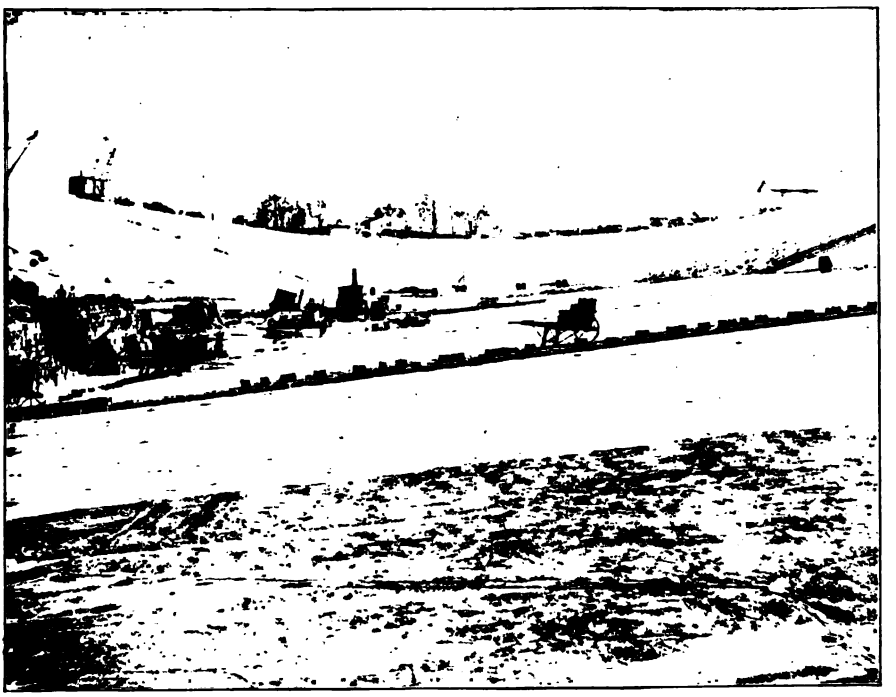
DESCRIPTION OF PLANT,

SITE.

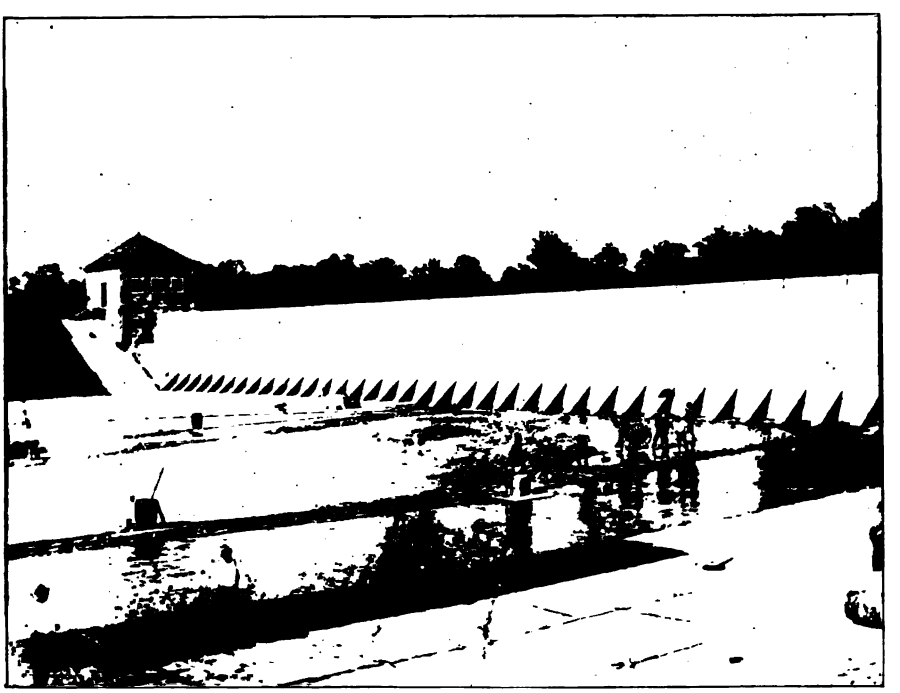
The selection of the site of the purification works at California, about 8 miles above the center of the city, was made, first, because there is little pollution of the Ohio River above that point, and second, because of the natural topography of the ground which was particularly well suited for the construction of the plant as contemplated. The valley of the river has been eroded by glacial action and subsequently partially filled with drift in the form of three terraces on the Ohio side. The lower terrace is at an elevation 60 feet above low water, is subject to overflow, and was raised by an artifical embankment to an elevation

Cincinnati. — Intake and River Pumping Station from Kentucky Side of River.

Cincinnati. — General View of Coagulating Basins and Filter Plant.



Cincinnati. — Settling Basin During Construction.



Cincinnati. — Coagulating Basin During Construction.

of 70 feet above low water in the river. On this was built the low service pumping station. The second terrace, not so well defined, is at an average elevation of 100 feet above the river, and the filter plant was placed on this after it was suitably graded. The third terrace is about 165 feet above the river, and contains two parallel ravines 2,000 feet long separated by a high, narrow ridge, and forming an ideal location for reservoirs. It is at this point that sedimentation basins were constructed.

Intake.

The intake for the waterworks comprises a large masonry tower and shaft, near the center of the channel of the river, about one mile above the mouth of the little Miami River. The minimum depth of water at the intake is 20 feet. The shaft contains two openings, one for use during high and one during low stages of the river, provided with movable wire screens. Water is taken through these screened openings into a shaft and carried through a 7-foot brick-lined tunnel, 1,426 feet long, to another shaft beneath the pump well of the low service pumping station.

Low Service Pumps.

Four pumps of 30,000,000 gallons capacity each, built by the Camden Iron Works, are provided to lift the water to the settling basins, and are placed in a large open well 98 feet in diameter, the bottom of which is 85 feet below the ground and 10 feet below low water in the river. The construction of this pit offered considerable difficulties and, as the bottom was not carried to rock, it was found necessary to counteract the lifting tendency of the water during high stages of the river by a large mass of cast iron.

Settling Reservoirs.

The water is forced by the low service pumps through two 60-inch cast iron pipes to the settling reservoirs which are located about one-quarter mile back from the river. These basins cover about 45 acres and the distance around each is about one-mile. The total capacity of reservoir No. 1 is 185,000,000 gallons and of No. 2 is 203,000,000 gallons. Their available capacity, however, is but 157,500,000 and 172,500,000 gallons respectively, and their total available capacity 330,000,000 gallons. This corresponds to a storage of 2.9 days at 112,000,000 gallons per day. At the present consumption, approximately 43,000,000 gallons per day, the available storage provided in the reservoirs is 7.7 days. It is intended to operate the basins on the "fill and draw" method, but their inlet and outlet piping are so arranged that it is also possible to use them either in series or in parallel.

The inlet to the reservoirs is a 72-inch pipe, which discharges through a chamber and over cascades 18 feet wide, constructed in the side slopes and extending to the bottoms of the reservoirs. A spillway connecting the two reservoirs is provided to prevent possible danger of overflow. Two 60-inch effluent pipes carry the water by gravity from the settling basins to the filter plant. Float tubes connected to the 60-inch effluent pipes by movable joints constantly maintain the point of discharge about 4 feet below the surface of the water contained in the reservoirs. For flushing purposes, three openings to a 30-inch drain pipe are provided in reservoir No. 1 and four in No. 2. These openings are controlled by 30-inch hydraulic mud valves. Eight and ten-inch water pipes are placed around each reservoir to assist in flushing, and water is furnished to them by a special pump operated under high pressure (about 100 lbs. per square inch).

The settling reservoirs were so laid out during construction that the necessary excavation and embankment balanced as nearly as possible. The bottoms and slopes of the reservoir are covered with concrete, brick and asphalt, and are water tight.

General Arrangement of Filter Plant.

The filter plant comprises three coagulating basins, a filter house, the necessary apparatus for preparing and applying the coagulant solutions, and a clear well. Before describing in detail these various features, it will be necessary to consider the general arrangement of the plant. (See Plate III.)

While it would perhaps have been best to so arrange the plant that the apparatus for preparing and applying the coagulant solutions would be contained in a central building and the filters placed in two wings attached to this central building, owing to the limited space available on the site of the plant, such an arrangement was impossible. As constructed, the filter building comprises three separate parts, the central part containing the filters, while at one end of this building was built the "chemical house" where the coagulants are stored and prepared for application, and at the other end of the filter house near the coagulating basins was built the "head house." This contains the controlling devices for regulating the supply from the settling reservoirs to the coagulating basins, together with the offices, laboratories, wash water pumps, suction well and various smaller pieces of apparatus for use in the plant. The coagulant is applied in the head house also, and it is necessary to carry the coagulant solutions through the entire length of the filter building.

The elevation of high water in the settling basins is 145, and the water flows from the basins by gravity through two 60-inch pipes to the head house into which it is introduced by six lines of 36-inch pipe, each of which lines terminate in two 24-inch balanced valves operated by floats. These pressure regulators are provided to maintain a constant elevation of water in the head house, but they have not proven efficient at the time of writing this report from the fact that the high velocity of the water in the valves causes sufficient impact to make the valves unbalanced.

The coagulant is applied in the concrete channel into which the 36-inch pipes discharge, and the coagulated water is then carried through two lines of 60-inch pipe into the first regulating chamber. A Venturi meter is provided in each of these 60-inch lines. At the point of entrance into this first regulating chamber is applied the lime solution. From this first chamber the coagulated water may be carried into any one or all of the coagulating basins through which it flows by gravity and is applied to the filters. The effluent from the filters discharges into the clear well from which it flows by gravity through a brick-lined tunnel, 7 feet in diameter, to the high service pumping station.

Coagulating Basins.

The coagulating basins are three in number and are located adjacent to the filter house and approximately at the same elevation. Basins Nos. 1 and 2 are each of approximately 10 million gallons capacity and are separated by a concrete dividing wall. Basin No. 3 is considerably smaller with a capacity of but 2 million gallons, and is provided principally to enable a secondary application of coagulant before applying the water to the filters.

The pipe used in the various inlets and outlets to the basins is of steel, 84 inches in diameter and extends along the full length of the basins. The outlet pipes of all the basins, and the inlet to No. 3, which may serve as an outlet, have openings or nozzles at regular intervals 4 feet below high water level. The inlet nozzles of Nos. 1 and 2 are 16 feet below high water and 6 feet above the bottom of the basins. The inlet and outlet piping to the basins are controlled by valves, and it is possible to use any one or all of the basins either in parallel or in series. When the plant is operated at 112 million gallons daily, theoretical periods of co-

agulation of .4 hour, 2.1 hours, 4.3 hours and 4.7 hours, respectively, may be obtained by the proper manipulation of the valves in the several valve chambers.

For the removal of sludge, two openings controlled by hydraulically operated mud valves are provided in each basin. Hose couplings attached to a pipe carrying water under 100 pounds pressure are located at intervals around the basins to be used in furnishing water for flushing purposes.

Coagulating System.

The problem of properly coagulating the water required the determination of both the most satisfactory coagulant to be used and the best means for its application to the water. Subsequent to the preliminary investigations, the attention of the Water Commissioners of Cincinnati was called to the use of copperas and lime in place of alum, and as no conclusive evidence was at hand relative to which was the more economical and efficient, the plant is so arranged that either aluminum sulphate or copperas may be used.

On account of the large quantities of coagulant that it is necessary to handle, the storage of solutions would require a very large space, and on this account and also because it was thought more efficient, it was decided to install a direct method of applying the coagulants without storage in a manner similar to that developed at St. Louis. This is accomplished by introducing a constant weight of the dry chemical at stated short intervals of time into a tank through which a stream of water is passed upwards. With this procedure there soon develops the condition that the quantity of chemical carried away in the solution is equal to that introduced, and the solution maintains very nearly a constant strength.

The question of handling the lime as a lime water or as a strong milk of lime was considered, and it was eventually decided that there was greater ease in regulating both the quantity and strength of lime water. The handling of the lime either in bulk or in barrels or bags was also considered, and it was ultimately decided that, although somewhat more expensive, its handling in bags would be more satisfactory, and would eliminate trouble from dust.

Coagulants. The chemicals in use at the present time are sugar copperas, obtained from the American Steel & Wire Company of New Jersey at $12 per ton, and a Bedford, Ind., lime obtained from a local dealer in Cincinnati at $6.60 per ton. Both the copperas and lime are furnished in bags containing 100 pounds. The bags for lime are owned by the city of Cincinnati. An additional charge for shipment in 100-pound bags is made for the copperas, which is generally shipped in 200-pound bags.

The specifications for the coagulants contain the following:

"The lime shall be best quality fresh burned lime, crushed so as to contain no lumps larger than 2½ inches in any direction. It must be free from hard or any unburnt stone or other foreign material and in every respect be equal to the sample submitted with the bid. No sample containing less than 80 per cent. of calcium oxide soluble in cold, distilled water will be considered.

"As the uniform quality of the lime or sulphate of iron equal in character to the sample submitted is an essential condition of this contract, fifteen (15) cents per ton shall be deducted for each per cent. of soluble calcium oxide which the lime shall contain less than three (3) per cent. below the soluble calcium oxide contained in the sample submitted with the bid, and twenty (20) cents per ton shall be deducted for each per cent. of soluble sulphate of iron which the salt shall contain less than one and one-half (1½) per cent. below that contained in the sample submitted with the bid, samples for the above determination to be taken at a rate of not less than one from every twenty bags.

"The sulphate of iron shall be of the composition $FeSO_4$, $7H_2O$ and shall be in the form of very fine grained crystals and what is known as 'sugar sulphate of iron.' It must be free from impurities and must in every respect be equal to the sample submitted with the bid. No sample containing less than 98 per cent. of sulphate of iron of the above composition or over 2 per cent. of matter insoluble in cold, distilled water, will be considered."

Means of Applying Copperas.

Both of the dry chemicals are taken into the lower story of the chemical house by a spur track and are lifted by elevators to the top story where room is provided for storage. This room also contains the apparatus provided for applying the chemicals.

Coagulant Tanks.

The tanks provided for the preparation of the coagulant solution are five in number, each 5.0 feet in diameter and 14.3 feet deep. In the center of each is a verticle tube with a flaring cone bottom, while about midway in the tank is a connection for the introduction of the dry coagulant into the tube. In this tube is an electrically driven horizontal propeller which ensures a constant circulation of water in the tanks.

Two lines of 3-inch cast iron pipe extend from the coagulant tanks through the filter house and terminate in two vertical pipes containing ½-inch perforations 12 inches apart. These pipes are placed in a concrete channel in the head house, through which the water passes on its way to the coagulating basins.

Filtered water is used to prepare the coagulant solutions and meters are provided to measure the quantity of water used.

For a secondary application of the coagulant, two lines of 3-inch cast iron pipe extend from the solution tanks to the valve chamber at the entrance to the last coagulating basin, where the method of application is similar to that in the head house.

Means for Applying Lime.

Lime Slakers. For slaking the lime, six steel tanks, each 6.0 feet in diameter and 2.8 feet deep, holding 600 gallons, are provided immediately above the lime saturators. They contain electrically driven rakes or agitators which insure a constant circulation of the solution. The tanks discharge near the top through screens into 3-inch wrought iron pipes leading to the saturators. Water heaters are provided to heat the water used in slaking the lime.

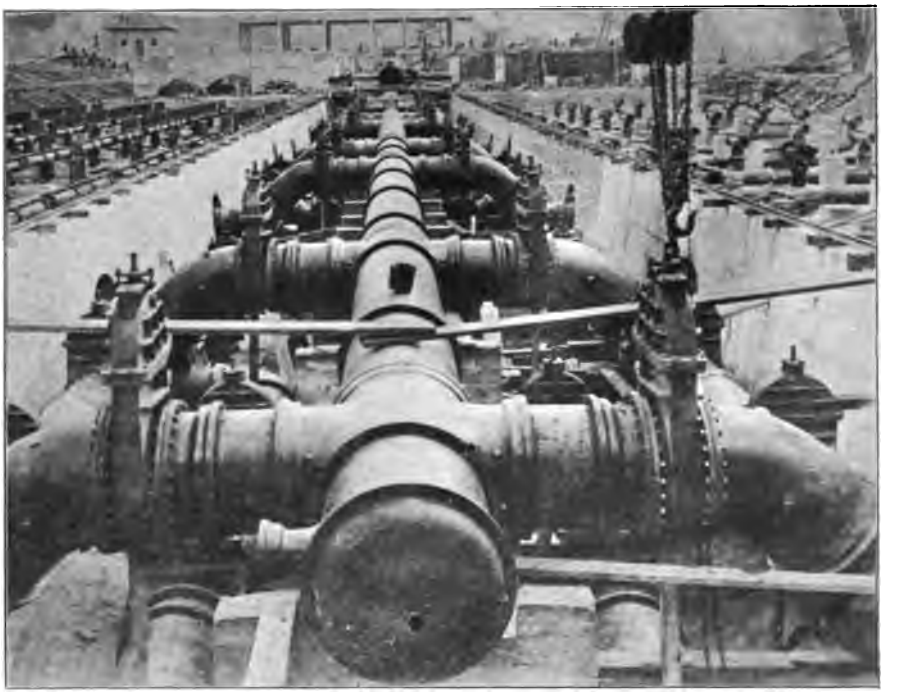
Lime Saturators. Four concrete saturators of octagonal section are provided, each 21.5 feet deep and of an average cross section of 262 square feet. In the center of each saturator is placed a vertical tube with a flaring cone outlet. The discharge pipe from the lime slakers enters this tube near the center. Each saturator contains a revolving agitator of steel veins near the bottom, driven by an electric motor.

The outlets from the saturators discharge into a 24-inch cast iron pipe, 600 feet long, which joins the 60-inch pipes leading from the head house to the coagulating basins at a point about 10 feet from the first valve house.

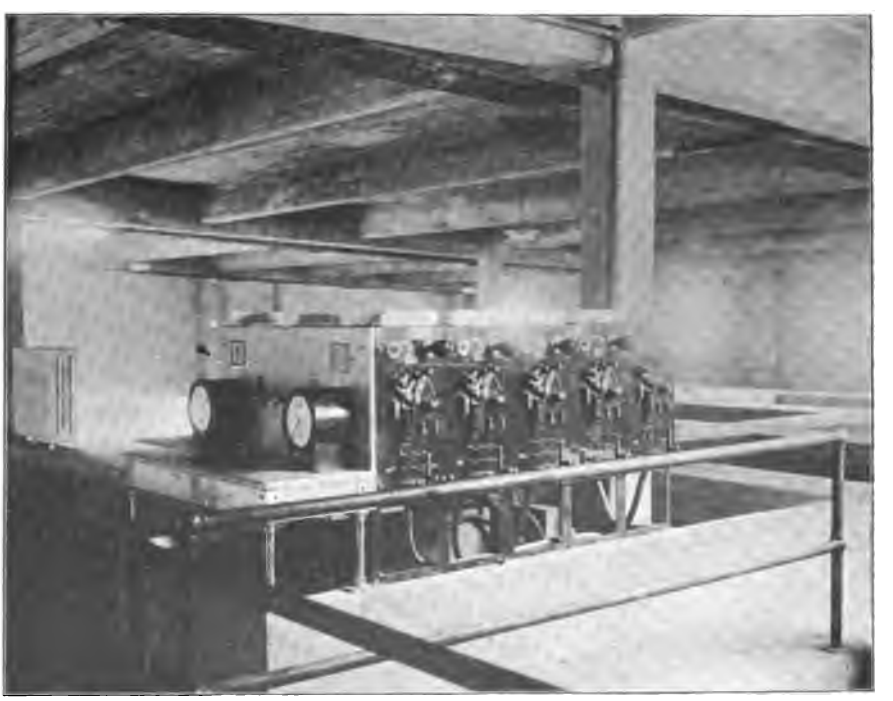
An automatic rate controller of a type similar to those provided for the filters is placed in the supply pipe to each saturator.

Filters.

The filter plant comprises 28 gravity filters, each 28 feet by 50 feet at the sand line, with an area of 1,400 square feet and a nominal capacity of 4,000,000 gallons in 24 hours. Each filter is practically divided into two independent units



Cincinnati. — Pipe Gallery and Filters During Construction.



Cincinnati. — Operating Switchboard for Filters.

by a central gutter, 5 feet wide, extending through its entire length. The tanks are of reinforced concrete construction, built as monoliths, and the entire sand area is always readily inspected from the fact that the side walls of the filter house are supported on the end walls of the filters.

Strainer System. In designing the strainer system, it was endeavored to keep all of the parts as accessible as possible. A detail of the strainer system is shown in Plate IV and in general it may be said that it consists of perforated brass plates covering channels in the concrete, into each of which enter four 3½-inch cast iron risers leading to the main collecting pipes. The plates are fastened at one foot intervals by brass hooks to rods embedded horizontally in the concrete channels. It will be possible at any future time to remove any or all of the plates in case this may become necessary. Each plate is approximately 3 feet long, 1/12-inch thick and contains 64, 3/32-inch holes per lineal foot. In the wedge-shaped space above the plates are placed four grades of screened gravel, ranging from 1 to 1/12-inch in size on top of which is fastened a wire screen of 10 meshes to the inch, and made of No. 20 brass wire. This screen is necessary on account of the high rate at which the wash water is applied.

Filtering Material. On top of the brass screen is the filtering material, 36 inches deep, consisting of washed sand from the Ohio River. This was obtained from a local contractor at $1.25 a yard, and washed on the ground by the Commissioners of Waterworks. It was found impossible to obtain bids from local contractors to furnish sand of a suitable quality for the filters, so that bids were obtained on a sand which nearest approached the required material in respect to size.

The sand used has an average effective size of .31 m. m. and a uniformity coefficient of 1.6. Although all of the sand placed was of practically the same effective size, it has since been graded by the wash water from about .2 m. m. effective size at the top of the filters to a much coarser size at the bottom.

Washing System. A departure is made from the usual method of washing mechanical filters in that no agitation is provided other than that obtained by a high rate of washing. The filters were designed for an application of wash water at the rate of 2.5 vertical feet per minute. The wash water is applied by gravity from a concrete tank holding about 160,000 gallons, located on high ground about 40 feet above the filters. This tank is supplied by two electrically driven pumps each of 2,500 gallons per minute capacity. These pumps have electrically controlled devices by which one is started in service when there is a drop of one foot in the storage tank, while the other is started when the drop in the tank is 2 feet or more. The suction well for the pumps is contained in the lower part of the head house to which filtered water is conveyed by a direct connection to the main effluent piping at the north end, and also by a 24-inch connection leading to the effluent piping in the other end of the filter house.

Concrete lateral gutters, 14 inches wide and with a maximum depth of 21 inches, are provided to remove the dirty wash water. There are six of these gutters in each half of a filter. The tops of the gutters are 30 inches above the sand.

Automatic Devices. Automatic rate controllers are provided for each filter. They consist of double-disk balanced valves, moved by hydraulical power of an outside source. The application of the hydraulic power is controlled by an auxiliary valve containing a diaphragm which is moved by the change in difference in pressure of the water on the two sides of a fixed orifice in the effluent pipe.

Loss of head gauges are provided for each filter, and indicate by three dials the height of water on the filters, the height of water in the effluent, and the difference between the two, commonly called the "loss of head."

All of the valves for the filters are electrically operated, and each filter is controlled from a central switch-board of five panels, one for each filter valve.

The switch-boards for two adjacent filters are placed back to back and 4 feet apart, while the space between is closed at one end by a panel containing the loss of head gauges and a sink into which is discharged the effluent from the sampling pumps of which one is provided for the effluent of each filter.

Clear Well.

The effluent from the filters is carried through two 60-inch cast iron pipes and discharged over a weir into the clear well. This is an open basin of 160,000 square feet area, and a capacity of about 19,000,000 gallons. Although uncovered at present, provisions for concrete piers were made in placing the water-proof bottom in case it is found necessary to cover the basin at any future time. The inlet to the reservoir is a reinforced concrete conduit extending the full length of the basin. In the top of this conduit, circular openings of cast iron are set at regular intervals about 7 feet below high water. The discharge from the clear well is by a similar arrangement, and is carried into a shaft at one end of the 7-foot tunnel leading to the high pressure pumping station on Eastern Avenue, Torrence Road, This tunnel is 22,264 feet long, and its upper end is 60 feet below the low water level of the Ohio river.

High Service Pumping Station.

A new high service pumping station was constructed during the present improvements of the supply, and contains three vertical triple expansion engines of 25 million gallons capacity each, and three of 12 million gallons capacity. From this station the low service supply is pumped to Eden Park reservoir, where there is an available storage of 100 million gallons. The high service is also pumped from this station by the 12 million gallon pumps. The entire pumping capacity of this plant is 111 million gallons per day and it supplies the entire city with the exception of one small section, to which water is pumped from the Western Hills station.

EXAMINATIONS.

The Cincinnati water purification plant was started in operation November 1, 1907. Since January, 1907, however, all of the high service supply was taken from above the city at California, and since May, 1907, a portion of the low service supply also was obtained from California. Since September 1, 1907, and until November 1, 1907, the entire supply was obtained from California and partially settled in the basins. Subsequent to November 1, the entire supply has been filtered.

Owing to the comparatively recent date of beginning its operation it has been impossible to make a complete examination of the plant in connection with this investigation, but the plant was inspected on November (21-22), 1907, and May 1, 1908. No samples were taken for analysis. Operation was started while construction was still in progress and before tuning up, so that analytical data with reference to results obtained would have little significance. At the time of the last inspection the construction of the plant was practically completed with the exception of one of the settling basins.

OPERATION AND EFFICIENCY.

The plant is operated continuously and is in charge of a superintendent. His assisting force is as follows: two assistant analysts, one night foreman, three filter attendants, one foreman in chemical house, one machinist, one janitor and

ten laborers. The night foreman is in charge of the entire plant during the night. The operation of the filter house is divided into three shifts of 8 hours each, and is accomplished by three filter attendants.

Average Daily Consumption.

At the time of the inspections the average daily consumption was approximately 42 million gallons per day, and it is interesting to note that this figure is considerably less than the previous estimated consumption as obtained by the rating of the old pumps. The actual quantity of water handled by the plant is accurately measured by the Venturi meters in the head house, but owing to the limited time during which the plant has been operated, no figures are at present available showing the ranges of daily consumption.

Preliminary Sedimentation.

As previously stated, the construction of one of the settling basins it not yet completed. Under the usual present condition of operation raw water is pumped continuously into the settling basin at the inlet and flows directly across to the outlet. On this account the displacement actually obtained in the basin is very much less than will be the case when it is used on the fill-and-draw method.

During the inspection of May 1, 1908, it was learned that the average bacterial removal accomplished by the basin is about 50 per cent., and also that approximately one-half of the suspended matter of the raw water is deposited in the basin. The storage provided in the basin has proven of very great value during the winter when occasional trouble from anchor ice was experienced at the intake.

Methods of Applying Coagulant.

Inspection of November 21, 1907. During the inspection of November 21, 1907, one line saturator, two slakers and one coagulant tank were in use. The charges of copperas (100 pounds each) were introduced at intervals of seventeen minutes into the dissolving tank through which water was supplied at the rate of 1.5 cubic feet per minute. There resulted a 7 per cent. solution.

The charges of lime (also 100 pounds each) were introduced into the hood over the lime slakers at intervals of twenty-one minutes each. The doors of these hoods are so arranged that, when opened, a fan in the vent pipes is automatically started causing an upward circulation of air away from the slaking tanks thus eliminating trouble from dust. The strong milk of lime formed in the slakers flowed by gravity into the saturator, through which water was passed at the rate of one million gallons daily. The theoretical strength of the lime water in the saturator was 48 grains per gallon.

The lime used during the early operation of the plant was of a very high grade and contained approximately 94 per cent. CaO. When one of the saturators was cleaned, after about three weeks service, there was found in the bottom but a very small deposit of sludge, not more than 3 inches in depth. As settled water from the basins is used in preparing the lime water it was expected that there would result a considerable deposit of sludge in the saturators, and the absence of such deposit was doubtless due to the excellence of the lime used.

The quantities of coagulant used previous to the inspection of November 21, 1907, were practically the same as at that time, and the total alkalinity of the water in different parts of the plant was as follows: these are average results of daily determinations from November 1 to 22, inclusive: Raw water, 39 parts per million; chamber "C" (coagulated water), 47 parts per million; entrance to clear well, 42 parts per million.

The mono carbonates in the coagulated and filtered water were as follows: Chamber "C," 17 parts per million; entrance to clear well, 10 parts per million.

The quantities of mono carbonates are of particular interest. The maximum quantity in the filtered water recorded was 17 parts per million, and yet there were complaints among the consumers from a white deposit, apparently incrustants of lime, formed on dishes during washing.

Inspection of May 1, 1908. During the inspection of May 1, 1908, copperas was applied at the rate of 1.5 grains per gallon, and lime at the rate of 1.1 grains per gallon. The filtered water contained about 5 parts of mono carbonates per million.

As has been the experience in most of the other plants in Ohio using copperas treatment, one of the greatest difficulties as yet encountered in the operation of the Cincinnati plant is in the proper application of lime. While the lime first obtained was very satisfactory and contained approximately 94 per cent. CaO, the recent shipments have been of very poor quality. At the time of the inspection the lime in use contained not more than 52 per cent CaO. On account of the penalty provided for furnishing lime of inferior grade, the present cost of this material is but 75 cents per ton,

Possibly on account of the poor grade of material, there results frequent stoppage of the discharge pipes from the lime slaking tanks to the saturators. It has been found necessary to provide connections to the water mains in order to flush out these pipes; also to occasionally knock down the pipes and scrape them out. This seems to be a necessary inconvenience of operation, but might perhaps have been somewhat eliminated by providing a straighter lime solution pipe.

In order to make possible a second application of lime, there has been provided a second solution pipe, of 8-inch cast iron, leading from the chemical house to the valve chamber at the entrance to coagulating basin No. 3. This chamber also contains the apparatus provided for the secondary application of copperas.

A difficulty in handling the lime, recently developed, is the fact that it absorbs such quantities of moisture that it swells and bursts the bags. On this account it is necessary to empty the bags on the floor of the storage room.

Since the inspection of November, 1907, there has been a reduction in the cost of copperas from the fact that 9 cents is refunded upon the return of each bag. The net cost of copperas is now about $10.50 per ton.

Quantity of Coagulants Used. It is generally the custom to use such a quantity of coagulant that the water applied to the filters has a turbidity of less than 50 parts per million. From October 21 to December 31, 1907, there were used 341,400 pounds of lime and 465,600 pounds of sulphate of iron, corresponding to an average quantity of 0.85 grain of lime and 1.16 grains of iron per gallon of water treated.

Coagulating Basins.

It is generally the custom to operate the two larger basins in parallel and the effluent from them is then passed through basin No. 3. This method of operation permits a second application of coagulant at the entrance of basin No. 3, when, for any reason, this may be necessary.

Previous to the inspection of May 1, 1908, each of the coagulating basins had been cleaned in turn. This had been accomplished without difficulty, although it was necessary to keep the larger basins out of service about two days.

During the inspection of May 1, 1908, it was learned that the results accomplished by the basins are very satisfactory. It was stated that the average bacterial removal was about 75 per cent. (based on raw water). The maximum quantity of copperas used previous to May 1, 1908, was 2.65 grains per gallon, at which time the efficiency of the filters was about 99.6 (based on raw water).

FILTERS.

Rate of Filtration. At the time of the inspection of May, 1908, attention of the operators was directed to rating the automatic controllers on the discharge pipes of the filters. These controllers have proven very satisfactory, and experiments indicate that they successfully control the rate of operation of the filters within from 1 to 2 per cent. The average rate of filtration is about 125 million gallons per acre per day.

Washing. The loss of head gages prove very efficient. The length of service of the filters between washings varies from 9 to 18 hours. The average length of run, except during flood stages of the river, is about 14 hours. Following heavy rains, however, both the length of run and the total loss of head are materially reduced. Although the maximum loss of head developed under normal conditions is about 9 feet following a 14-hour run, after heavy rains the maximum head developed without clouding of the filtered water is but 5 or 6 feet after a run of 9 or 10 hours. No investigation of the composition of the very fine suspended matter in the filtered water at such times has been made, but it is thought to be composed of the very fine silt in the raw water.

By experiment it was learned that the capacity of the lateral gutters without flooding was limited to an application of the wash water at a rate of 2.1 vertical feet per minute and the valve in the main wash water line is so adjusted that the maximum application of the wash water is at this rate. The wash water is applied to the filters at a gradually increasing rate so that the maximum rate is not reached until approximately one minute after the beginning of the wash. The total length of time during which the wash water is applied varies from two to four minutes. From October 21 to December 31, 1907, the average length of washing was 2.86 minutes.

During the month of November, 1907, there was used approximately 2.7 per cent. wash water, and in March, 1908, 4.4 per cent. From October 21 to December 31, 1907, the total quantity of water filtered was 2,804,000,000 gallons, of which 74,350,000 gallons, or about 2.65 per cent., were used to wash the filters.

During the inspection of May 1, 1908, there was made an examination of the filtering material to determine the possible formation of "after deposits" of lime or pockets resulting from poor washing. The sand appeared clean and no evidence indicating deposits was noted. It was observed that there is a very perfect hydraulic grading of the filtering material by the wash water, so that the coarser particles all remain at the bottom of the filter, while the finest grains are forced to the top. As previously stated, (Page 75) the effective size of the sand at the top is considerably less than 0.2 m. m. It would be interesting to determine whether this grading of the filtering material has any detrimental effect on the efficiency of the filters, particularly after periods of heavy rains when the raw water contains large quantities of fine silt.

Efficiency of Washing. The high rate of application of the wash water gives a very efficient wash and fully meets the expectations for the design. No sand has been detected in the wash water, and, while the total body of the filtering material is lifted during washing, no particles of sand have been found at a greater height than 6 inches below the top of the gutters. The back part of the filters does not wash as rapidly as does the front, although in designing the effluent piping it was figured that but approximately 0.3 or 0.4 foot loss of head would result in this piping during washing; as the total loss of head at a filter during washing is more than 5 feet, the loss in the piping between the back and front portion (0.4 foot) was considered negligible.

Growths in Clear Well.

During the inspection of May 1, 1908, there were noted considerable growths extending along the sides of the clear well. These growths were of various kinds, some appearing as green filaments and reaching a maximum length of about 1 foot, while others resembled fresh water sponge. The growths in all cases appear luxuriant, and it is probable that trouble will eventually result from odors or tastes in the water. On account of the comparatively small storage in the clear well, it will be impossible to remove these growths by copper sulphate, and probably they can only be eliminated by covering the basin. In constructing the floor of the clear well provisions were made for future addition of covers if necessary.

Typhoid Fever Statistics.

In the following table is shown the number of cases and deaths from typhoid fever for the years 1905-6-7 and a portion of 1908. The table shows a considerable reduction in the typhoid fever death rate, particularly since March, 1907, a reduction which is undoubtedly due largely to the improved quality of the public water supply. In explanation of the table it should be stated that since January, 1907, the high service supply has been taken from above the city at California; that since May, 1907, a portion of the low service supply also has been obtained from California; that subsequent to September all of the city water has been pumped from California and also partially settled in the settling basin; and that subsequent to November 1st, all of the supply has been filtered.

Month.	1905.		1906.		1907.		1908.	
	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.
January	98	15	92	22	24	24	17	3
February	67	13	86	19	199	16	21	8
March	74	20	72	17	185	23	17	8
April	48	12	78	17	117	16	10	5
May	48	12	106	11	99	6	17	6
June	46	9	452	31	91	16	9	3
July	60	12	286	31	96	15	21	6
August	46	14	275	34	91	13	24	5
September	55	13	123	17	62	5	.....	.....
October	55	7	87	14	50	10	.....	.....
November	38	9	115	11	28	7	.....	.....
December	111	19	168	15	23	6	.....	.....
	746	115	1,940	239	1,252	157	.....	.....

COST OF INSTALLATION.

In Table No. 3 is shown the cost of providing the purification works as separate from the other waterworks features necessary without purification. In the last two columns in this table are shown, respectively, the cost per million gallons capacity of each unit and the cost of the same per million gallons filter capacity. The total cost per million gallons filter capacity, $49,830, is unusually high and includes two especially large items, low service pumps and settling reservoirs. It should be stated that while the first cost of the pumps is high,

their operating cost is low; also that the provision of the settling reservoirs increases the economy of operation and permits of greater ease in obtaining satisfactory results, particularly during periods of high turbidity in the river water. This last point is of considerable importance, as for this reason it was considered advisable to provide the settling basins, although greater economy might perhaps have resulted with the use of larger coagulating basins without preliminary sedimentation.

The figures shown in the table are only approximately correct, as final payments had not been made on part of the work at the time of writing this report.

TABLE NO. 3.

Cincinnati—Cost of Installation of Purification Works.

Item.	Million Gallons Capacity.	Total Cost.	Cost Per Million Gallons Capacity.	Cost Per Million Gallons Filtering Capacity (1).
ADMINISTRATION	.....	$500,000 00	.....	$4,470
EXPT. PURIFICATION PLANT	.....	41,672 81	.....	370
REAL ESTATE	.....	115,792 50	.....	1,034
MIAMI RIVER PROTECTION	.....	55,125 23	.....	492
INTAKE	.....	237,037 85	.....	2,120
LOW SERVICE PUMPS	120	1,634,149 19	$13,600	14,600
PUMP MAINS—To Set. Res.	120	186,383 25	1,553	1,664
PIPE LINE—Set. Res. to Filters	.....	54,486 45	.....	487
PIPE LINE—Filters to Clear Well	.....	29,432 84	.....	263
SETTLING RESERVOIRS	330	1,491,941 54	4,480	13,310
COAGULATING BASINS	22	315,736 74	14,340	2,817
FILTERS—COMPLETE	112	759,661 53	6,780	6,780
CLEAR WELL	19	127,705 26	6,720	1,140
ROADS AND OTHER EXPENSES	.....	31,840 50	.....	284
Total	.....	$5,580,965 19	.....	$49,830

(1) Based on a total filter capacity of 112 million gallons.

COST OF OPERATION.

In the following table is shown the cost of operating the Cincinnati filter plant from October 21, to December 31, 1907.*

The first item is for coal used for heating the buildings. In considering these costs it should be remembered that the present daily consumption is but 42 million gallons per day, and that the ultimate capacity of the plant is 112 million gallons per day. On this account the fixed charges per million gallons for heating, power and light, and labor, are proportionately large. The total cost of filtering per million gallons, $3.98, does not include any of the costs of operation at the intake pier ($4,020.37) or river pumping station ($35,958.72).

364 tons of coal, including cost of delivery	$1,073 60
170.7 tons of lime at $6.60	1,126 62
232.8 tons of sulphate of iron at $12	2,793 60

*Ref. Report of Bd. of Trustees, Commissioners of Waterworks, 1907.

Labor for unloading lime and iron	114 70
Cost of power and light	1,387 06
Various supplies	250 00
Maintenance and repairs	117 48
Pay rolls	3,737 46
74,350,000 gallons wash water at $3.60 per million	267 66
Total cost of filtering	$10,868 18
Total number of gallons filtered (including wash water)	2,804,000,000
Total cost per million gallons delivered	$3 98

CONNEAUT.

The city of Conneaut is in the extreme northwestern part of Ohio in Ashtabula County on Lake Erie. In 1906 its population was estimated at 9,000, of which there is a large percentage of foreign labor employed in the ore handling industries. The city is divided into two parts — the main business portion, which is back from the lake, and the harbor at the mouth of the Conneaut river. At the latter are to be found docks with their ore handling machinery and railroad yards, while in the main part of the city are some general manufacturing establishments.

HISTORICAL.

The water works were first installed in 1889 by the Conneaut Water Company, and comprised an intake on the shore of Lake Erie at Conneaut Harbor, a pumping plant of 2,000,000 gallons capacity housed in a substantial brick building, a steel standpipe for storage and fire protection, and a distributing system.

The supply was first taken from a series of driven wells along the shore of Lake Erie, near the pump house, but it was found impossible to obtain sufficient water and the wells were abandoned after two years' use. A new supply was then derived from seven, 6-inch, No. 6, Cook tubular wells, driven horizontally in the sand from 4 to 5 feet below the bottom of the lake, and extending 20 feet from the shore line. The suction of the pumps was directly attached to the wells, and water was pumped through the sand bottom of the lake into the standpipe, from which it flowed by gravity into the distributing system. A 12-inch emergency suction was laid along the bottom of the lake and extended 300 feet from the shore line. This was to be used only in case of emergencies. Back-flushing of the wells was provided, using water from the stand-pipe, and it was found necessary to so flush them out every two or three days.

This supply proved of satisfactory quality, but as the consumption increased, it was found impossible to obtain a sufficient quantity of water from the wells. In 1899 the consumption was increased from 700,000 to 1,000,000 gallons daily, and it became necessary to use the emergency intake, and to augment the supply by unfiltered lake water.

Conditions Leading to Purification.

In the summer of 1899 there was an epidemic of typhoid fever at Conneaut, which was investigated by the Secretary of the State Board of Health, and the evidence obtained tended to show conclusively that the prevalence of the disease

was due to the pollution of the water supply, particularly at such times as lake water was pumped directly into the mains. There were 94 cases and 12 deaths reported in this epidemic.

One of the points brought out in the above investigation was that, although the lake water at the intake of the waterworks generally showed little if any pollution, yet there were times, particularly during easterly winds, when the supply consisted of lake water intermixed with water from the Conneaut river. The latter is badly polluted by the sewage of Conneaut, all of which is discharged directly into the river without purification. The prevailing winds on the lake are from a westerly direction and there is generally a decided surface current of the water in the lake from a westerly direction, during which times the river water is carried toward the east and away from the waterworks intake. During times of easterly winds the currents in the lake are reversed, and the river water flows over the intake, causing a serious pollution of the water supply.

As a result of the above investigation, plans for the filtration of the supply were submitted to the State Board of Health, and approved by them in 1899.

DESCRIPTION OF PLANT.

In 1900 a filter plant was built by the O. H. Jewell Filter Company, comprising two gravity mechanical filters of 800,000 gallons capacity, housed in a substantial brick building, which also contained a small clear well for the storage of filtered water. As the consumption increased, another gravity mechanical filter, built by the Pittsburg Filter Manufacturing Company and having a capacity of 400,000 gallons daily, was added in 1904. The two original filters were provided with small settling compartments beneath, but no provision for sedimentation was made in the filter added in 1904. In 1905, a new intake was built, by which water was taken at about 1,500 feet from the shore of the lake.

During the special investigation by the State Board of Health, the plant has comprised the following general features: A rock-filled crib intake, from which a 5-foot brick tunnel extends to a forebay containing a 16-inch cast iron suction for a low lift pump; a filter plant comprising three units, each of 400,000 gallons capacity daily, two of which are provided with small settling compartments, while the third has no provision for sedimentation; a small clear well for the storage of filtered water; a high service pump; a steel stand-pipe and a distributing system.

The filtration plant added in 1900 and 1904 is housed in an addition to the pump house, which addition also contains the raw water pump and clear well. The building is a substantial brick structure located on the shore of Lake Erie in Conneaut Harbor, about one mile from the center of the city.

Intake and Raw Water Pump.

The intake is a 14'x14' rock-filled crib about 1,500 feet from the shore line, and 2,000 feet west of the mouth of the Conneaut river. The depth of water at the crib is 18 feet and the supply is taken practically from the bottom of the lake. From the intake, a 5-foot brick tunnel, 1,500 feet long, carries the water to a brick-lined well about 6 feet in diameter and 40 feet deep. From the latter a 16-inch cast iron suction, approximately 200 feet long, carries the water directly to the raw water pump, which is of a horizontal duplex type and has a capacity of 2,000,000 gallons in 24 hours. It has been necessary to operate this pump at comparatively high speeds during part of the day, and its operation has not been economical. In December, 1907, a new raw water pump was installed which is an impeller pump, built by the DeLaval Machine Company, and has a nominal capacity of approximately 2,000,000 gallons per day.

Coagulating System.

Coagulant. The coagulant used is a standard brand of aluminum sulphate obtained from the Erie Chemical Company of Erie, Pa.

Solution Tanks. The coagulant is dissolved and stored in two wooden tanks in the pump room. These tanks are each 5 feet in diameter by 8 feet high with a capacity of 1,175 gallons.

Method of Application. The coagulant solution is carried by a 1-inch brass pipe to a regulating box, in which a constant depth is maintained by a float valve. From the regulating box the solution flows by gravity through a 1-inch brass pipe and is discharged into the 16-inch suction near the pump. The quantity of solution applied is regulated by a globe valve in the solution pipe near the regulating tank.

Coagulating Basins. As previously stated, the filter added in 1904, generally called filter No. 3, has no provision for sedimentation. Filters Nos. 1 and 2 are similar to those used at Dennison, Ohio, detail drawings of which are shown in Plate V. It will be seen that there are small compartments beneath each filter, 16 feet in diameter and 7.7 feet deep, with a total capacity of 23,200 gallons. At the usual rate of filtration, 810 gallons per minute, the coagulating period for filters 1 and 2 is 43 minutes.

Following the recommendations made during the special investigation, two new coagulating tanks were added in December, 1907. These were formerly used at Elyria and comprise two wooden tanks each 30 feet in diameter by 15 feet high, with a total capacity of 159,000 gallons. The raw water is pumped into these tanks generally at a rate of about 810 gallons per minute, so that the average time for sedimentation in the tanks is 3.3 hours. In filters 1 and 2, there is an additional coagulating period, so that the total time for sedimentation in these filters is 4.0 hours.

Filters.

The filter plant comprises three wooden tubs, each 15 feet in diameter and with a guaranteed total capacity of 1,200,000 gallons in 24 hours. At 125,000,000 gallons per acre per day, the total filtering capacity of the plant is 1,400,000 gallons. The strainer systems comprise manifolds of wrought iron pipes, into which are screwed brass strainers at 6-inch intervals. All of the filters contain about 8 inches of fine gravel screened through a ½-inch screen. Filters Nos. 1 and 2 contain 3'-6" of filtering material, consisting of round-grained sand with an effective size of .47 m. m. and .45 m. m., respectively, and a corresponding uniformity coefficient of 1.8 and 1.3. Filter No. 3 contains 3 feet of filtering sand, with an effective size of .47 m. m. and a uniformity coefficient of 1.3.

The filters are washed by a reverse current of water obtained from a 4-inch connection to the force main in which the pressure varies from 40 to 90 pounds per square inch, depending on the speed of the filtered water pump. The dirty water flows over the top of filters 1 and 2 into the space between the two tubs, while in filter No. 3 an annular trough is provided around the inside of the tank for the removal of the wash water. No loss of head gages nor automatic rate controllers are provided.

Storage of Filtered Water.

Clear Well. The clear well is contained within the filter house, and consists of a concrete basin of irregular shape, with a maximum depth of 4.6 feet and a total capacity of 12,600 gallons. The usual rate of pumping gives a storage of 16 minutes when the clear well is full, but as the working depth is but 1.5 feet, the available capacity is 6,900 gallons, corresponding to a storage period of but

9 minutes. The total available head on the filters when the clear well is full is about 8 feet.

High Service Pumps and Stand-pipe. From the clear well the filtered water is pumped to the stand-pipe by a cross compound crank and fly wheel pump, which was built by the Laidlaw, Dunn, Gordon Company, and has a nominal capacity of 2,000,000 gallons per day. The stand-pipe is in the east central part of Conneaut, near the Conneaut river, and consists of a steel tank 20 feet in diameter, 105 feet high, with a capacity of 247,000 gallons.

The pressure in the force main at the pump is about 80 pounds per square inch, while the pressure in the mains averages 45 pounds per square inch.

EXAMINATIONS.

During the special investigation by the State Board of Health, the plant of the Conneaut Water Company has been visited six times, on May 24th, June (20-21), September (11-12), December (14-15), 1906, April (1-5) and December 10th, 1907. Regular examinations were made on each of these visits except the first and last, when the plant was inspected.

The examination of April (1-5), 1907, was made by the assistant engineer, together with the special assistant engineer, at the request of the health officer for an examination of the water supply on account of the prevalence of typhoid fever in Conneaut. This examination included, not only an investigation of the methods of operating the plant and its efficiencies, but also a gathering together of climatological data showing air temperatures, prevalence of easterly winds, amount of rain-fall, and any features that would tend to influence the quality of the lake water at the waterworks intake. Information was also obtained relative to the history of the typhoid cases and to all possible sources of infection. A special report of this investigation is to be included in the annual report of the State Board of Health for 1907.

OPERATION.

When the plant of the Conneaut Water Company is in operation, water flows by gravity from the intake into the forebay and is lifted by the raw water pump through the coagulating basins onto the filters. The effluent from the filters flows by gravity into the clear well and is lifted by the high service pumps into the stand-pipe.

In the absence of storage it is necessary to operate the plant for 24 hours. Its operation is in charge of two shifts, from 6:00 a. m. to 6:00 p. m. During the night the operation is conducted entirely by one man who also does his own firing, and it is then the custom to operate the plant at somewhat slower rates than during the day, when two men are employed. The day engineer, who is assisted by a fireman, has responsible charge of the plant.

During the special investigation, daily records have been kept showing the operation of the plant and monthly averages of these records are shown in Table No. 5.

Average Daily Consumption.

From the daily records, it will be seen that the average daily consumption at Conneaut during the investigation has been 1,121,000 gallons. It is of interest to note that there is no marked increase in the daily consumption, nor is there any seasonal variation. The quantity shown includes also the wash water, so that the actual average consumption is less than the amount indicated in the records, and is 1,007,000 gallons.

General Methods of Operation.

At the beginning of the investigation, it was learned that the operators at the filter plant were without previous experience with mechanical filters and that their methods of operation were not such as would produce the best or most economical results. At the first examination, no automatic appliances were in use to assist in maintaining the operation of the raw water pump, filters and high service pump at the same rate. The general method of procedure was to pump the water, into which the coagulant had been applied, through the coagulating basins and up onto the filters, which were operated at varying rates. In order to prevent overflowing of the filters the valves in the drains for carrying away the dirty wash water were left open. If the filters were operated too fast the sand became uncovered, so that the applied water which spilled over the sides of the stand-pipe in the center of the filters formed deep holes in the sand. Conversely, if the filters were dirty and were not filtering sufficient water, there was an overflow of coagulated water through the drains and a considerable waste of water.

The storage provided in the clear well is of an extremely short period of time (9 minutes), which, for economical considerations, makes it necessary to operate the filters and high service pump at the same rate. If the filters operate too slowly there is a tendency for the high service pump to race, while if there is too great a discharge from the filters, there results a wasteful overflow from the clear well into the wash water drain.

At the first examination it was found that there was a frequent waste of coagulated water from the filters, also of filtered water from the clear well, and that there was no appreciation of the possible effect on the character of the filtered water by the excavations in the filtering material. It was then pointed out that for purposes of economy as well as for efficiency of results, it was necessary to use the automatic devices provided to maintain the raw water pump, filters and high service pump at the same rate. Following this examination, the automatic governor on the raw water pump and the floats on the inlets to the filters were repaired. The method of operation was then changed so that the proper depth of water is maintained on the filters. If the raw water pump tends to operate too fast there results an increase in the pressure in its force main due to the closing of the float valves on the inlets to the filters. This increase in pressure causes an automatic shut-off of the steam to the pump, the supply to which is regulated by a Fisher automatic governor.

Previous to these changes in operation, not only had there been a considerable waste of water at the plant, but also particularly at such times as the filtering material was uncovered, it was necessary to use unusually large quantities of wash water to force out the air which naturally accumulated in the filters. Not only were the filters washed at frequent intervals, but it was necessary every two or three hours to "blow" the filters, that is, to turn on the wash water for a short period of time in order to drive out the air.

Since the repairs to the automatic regulating devices have been completed, little trouble is experienced in operating the raw water pump, but as there is only 1.5 feet working depth in the clear well, constant attention on the part of the operator is required to maintain the clear water pump and the filters at the proper speed. An electric alarm is provided to give a signal when the water in the clear well is low and it is then necessary either to slow down the pump or to operate the filters at greater speed.

These changes in operation have resulted in an elimination of the waste of coagulated and filtered water, and have also very much improved the efficiency

of the filters. The ease of operation of the plant would be still more increased with a provision of greater storage of filtered water at the plant.

Application of Coagulant.

In preparing the coagulant solutions, a charge generally of 175 pounds of the dry chemical is introduced into a perforated box in the top of the solution tanks. By a connection to the force main, water is introduced into the perforated box through which it flows into the storage tanks and by the time the tanks are full the coagulant is entirely dissolved. The tanks are used in turn and the solution is prepared in one whilst the other is in service. By changing the strength or quantity of the solution it is possible to vary the quantity of coagulant applied. In practice, it is generally the custom to use a solution of constant strength and to change the quantity of coagulant applied by varying the quantity of solution.

Some trouble was experienced with the wrought iron pipes used to carry the solutions during the first part of the investigation, but in the spring of 1907, they were replaced with 1-inch brass pipes and no trouble has since arisen. In general it may be said that the means for applying the coagulant are very satisfactory, and permit of a fairly constant application or any variations desired.

At the beginning of the investigation but one grain of alum per gallon was applied, a quantity which was found to be too small with the short period of time allowed for coagulation in the tanks. It was recommended that the quantity be increased to 1½ and finally 1¾ grains per gallon. The average quantity applied during the investigations, as shown by the daily records, is 2.1 grains per gallon, while 2.4 grains per gallon were used during 1907. This quantity is large and is primarily due to the lack of coagulating capacity. During periods of high northerly winds the lake water is turbid and it is then necessary to increase the quantity of coagulant, as shown in the daily records, particularly during the spring months when the turbidity of the lake water is frequently as great as 200 parts per million.

Coagulating Basins.

The coagulating basins require little attention. It is generally necessary to clean each tank once in two weeks. The quantity of deposit removed varies somewhat but is generally at least one foot deep.

Filters.

Rate of Filtration. There is considerable variation in the rates of filtration, some of which variations have been shown to be necessary in the discussion of "General Methods of Operation." In the absence of automatic rate controllers the rate of filtration is controlled by the degree of opening of the valves in the effluent pipes from the filters. These valves are generally set to give about 3 inches drop per minute of the water surface in the filters and are not touched until a run is completed.

During the first two examinations it was the custom to wash all of the filters at the same time, a process which generally required one hour for its completion and during which time one filter was always out of service. As the filtered water pump was not slowed down, it was necessary that the output of two filters should equal the normal output of three, thus requiring that they be run at excessive rates which were occasionally found as high as 150 million gallons per acre per day. These high rates caused a decrease in the bacterial efficiency of the filters. It was advised during the first two examinations that a period of time be allowed between the washing of the different units, and that the filtered water pump be slowed down during washing. With these changes it is not necessary to operate the filters at such high rates immediately after washing.

As the total area of the filters is .0123 acre and the average daily consumption is 1,125,000 gallons, which are filtered in 23 hours, the average rate of filtration is 95 million gallons per acre per day. The rate during the night is somewhat less than during the day and is probably about 90 million gallons per acre per day. The small storage in the stand-pipe necessitates nearly as great variations in the quantity filtered as takes place in the consumption. The maximum hourly variation in consumption during the day is about 25 per cent.

Washing. No loss of head gages are provided and it is the custom to wash the filters at stated times, generally once in the morning and once again at night. When it is impossible to obtain a sufficient quantity of filtered water between washings, the filters are blown, a practice which, although tending to prolong the runs, probably causes a decrease in the bacterial efficiency of the filters. In order to avoid excessive rates immediately after washing, it is now the custom to allow as long a period of time as possible between the washings of the different filters. This is found necessary on account of the extremely small storage capacity of the clear well.

The filters are washed by a connection to the force main and the rate of application of the wash water varies with the degree of opening of the valve in this connection. The actual rate has been found to vary at the different examinations, but the average rate is 0.5 foot per minute for about 20 minutes, corresponding to 13,200 gallons, or 10 vertical feet per wash. The total number of filters washed during the day varies with the turbidity of the water in the lake. The maximum number of washes, as shown on the daily records, is 18 and the wash water was then equivalent to 21 per cent. of the quantity filtered. The average quantity of wash water shown on the daily records is 10.2 per cent. (See Table No. 5.)

Some leakage of sand has occurred, particularly through filter No. 3, as the strainers in this filter contain larger openings than those in the other two filters. It has occasionally been found that there was not a sufficient depth of sand in this filter to permit of a satisfactory wash, or to give the best bacterial efficiencies. In March, 1907, the filters were overhauled, the strainers cleaned, and the sand replaced to its original depth.

CHARACTER OF RAW WATER.

Until the last examination, it was impossible to obtain a single sample of the raw water representative of both bacterial and chemical content. Bacterial samples were taken from the top of the filters and represent coagulated rather than raw water, while the chemical samples were taken from the forebay about 10 feet below the surface. This difficulty was caused by the introduction of the alum into the suction of the raw water pump. Samples of lake water were also taken from a boat at the intake about one foot below the surface. In the examination of April (2-3), 1907, this difficulty was removed by providing a sampling tap in the discharge main of the raw water pump, and when samples were taken the alum was temporarily shut off.

Unfortunately, all of the examinations at Conneaut, with perhaps one exception, have been made at such times as would show the lake water in its best condition. During the winter of 1906-07 the lake water was unusually turbid, and in fact, at no time during this season was its turbidity less than 50 parts per million. The maximum turbidity during this period was probably about 200 parts per million. The examinations during the warm seasons show that the lake water at Conneaut contains but little suspended matter and dissolved color.

At no time has there been found a large number of bacteria in the lake water, and frequently the bacterial content has been very low. The evidence indicates that, except during periods of easterly winds, the satisfactory purification of the water requires simply a removal of the suspended matters, as no evidence has been obtained that indicates a pollution of the supply.

During the examination of April, 1907, a study of the conditions in the Conneaut river was made, and the results of the analyses then obtained are shown in Table No. 4. Four samples were collected, one from the lake at the intake to the waterworks, one from the lake just inside the east breakwater, one from the river at the beginning of the breakwater at its outlet, and just below the sewer outfall, and one from the river just above the B. & L. E. Railroad bridge. At the time of the examination there was a very heavy northwest wind blowing, making the lake unusually rough and the effect of the wave action on the character of the water is shown in the analyses by the high content of organic matter. The number of bacteria contained in the lake water also increased over the results obtained on the previous day, but there is no evidence showing a dangerous pollution by the organic matter contained. The effect of the discharge of the sewer outfall into the river below the railroad bridge is indicated by the large increase in the bacterial content of the river.

TABLE NO. 4.

Samples at Conneaut Harbor.

No. of Sample.	Bacteriar Per C. C.	Coli in 1 c. c.	Coli in 100 c. c.	Alk.	Total Solids.	Chlorine.	Free Am.	Alb. Am.	Nitrites.	Nitrates.	Oxygen Req.
1	2,000	0	+	73	410	9.5	.042	.362	.004	10.0	9.65
2	800	0	0	74	285	8.0	.018	.288	.003	10.0	9.60
3	14,500	+	+	48	217	1.2	.044	.240	.033	.....	7.75
4	7,800	+	+	45	169	2.3	.050	.174	.004	4.0	7.15

Sample No. 1. Lake at east breakwater.
Sample No. 2. Lake at intake to waterworks.
Sample No. 3. River at point inside breakwater.
Sample No. 4. River at railroad bridge.

The evidence shows a considerable pollution of the water in Conneaut River, and during easterly winds the course of the river over the intake can be readily traced by its color. At such times it is apparent that there will be a considerable pollution of the supply due to the sewage laden water of the river. Unfortunately, none of the examinations have covered periods of easterly winds, but it is apparent that at such times unusual care on the part of the operators of the filter plant is required in order to produce a wholesome water.

EFFICIENCIES.

GUARANTEE.

The contract covering the installation of the first two filters contains the guarantee that "When the raw water contains less than 7,000 bacteria per c. c. the effluent shall not contain more than 200 per c. c. When the raw water con-

tains more than 7,000, the bacterial removal shall be at least 97 per cent; that the effluent shall be bright, clear, free from suspended matter and color visible to the naked eye." The guarantee for filter No. 3 is that it will remove 98 per cent. of the bacteria when the raw water contains more than 3,000 per c. c. and that the effluent from the filter shall be satisfactory to the State Board of Health.

Intake.

During the examinations the shore line at the pumping station has receded about 50 feet on account of wave action. This recession is due partly to the hauling away of sand from the lake shore, and partly to the extension of the west breakwater at the mouth of the river. It is apparent that some protection will soon be necessary for the forebay, particularly from shore ice in the winter.

In the spring, a very large number of cyclops have been found in the forebay and on the filters. They have, however, disappeared later in the season. This experience is similar to that at Lorain, except that at the latter point they were found during a considerably longer period of time.

Coagulating System.

Although recommended when the filter plant was designed, a coagulating basin was not provided and during the investigations, one filter has been in service without any preliminary sedimentation of the applied water, while for the other two, the applied water has but three-fourths of an hour's sedimentation. Especially in the winter there was noted a decided difference in the character of the water which had received preliminary sedimentation and that which had not, as in the latter the coagulated masses were very much smaller and apparently unformed. The engineer stated that the filter using unsettled water requires more washing than the other two.

In general it may be said that although the methods of applying the coagulant have proven very satisfactory, on account of the very short period allowed for the coagulation and sedimentation of the applied water, not only has it been necessary to use unusually large quantities of coagulant and wash water, but at times it is impossible to satisfactorily filter the water.

Unfortunately, no examination has been made subsequent to the installation of the coagulating tanks in December, 1907, but their use will undoubtedly result in much greater ease of operation and greater economy both of coagulant and wash water.

Filters.

At each of the several examinations the average number of bacteria per c. c. found in the filtered water was less than 100. In but one examination; that of April, 1907, were any coli found in the filtered water and then in four out of twenty-one samples but only in 100 c. c. portions, and also in samples containing less than 100 bacteria per c. c. It is difficult to understand the significance of these coli results, unless they would indicate a less degree of efficiency of the filters previous to the examination. The investigations of the source of the typhoid at Conneaut during this examination indicate that is was undoubtedly due largely to the water supply, a fact whch would tend to give the coli results considerable significance as indicating recent pollution of the supply.

Investigations of Typhoid Fever at Conneaut.

Since the watterworks were installed there have occurred four epidemics of typhoid fever at Conneaut, in 1899, 1901-02-04. All of these epidemics were investigated by the State Board of Health. That of 1899 was evidently due to the

use of unpurified lake water, while those of 1901-02 were after the installation of the filter plant and were attributed to the use of too small quantities of coagulant. It has been stated, with perhaps good reason, that these investigations were not sufficiently thorough to warrant the placing of the source of the typhoid on the water supply.

The investigation of April, 1907, covered a period of six days, and in that time the history of all the cases that had occurred at Conneaut from December 1st, 1906 to March 31st, 1907, was carefully studied, particularly with reference to all possible sources of infection. The investigation covered not only a study of the history of each case, but also any features relative to the operation of the filter plant effecting the quality of the water supply. The evidence which tends to show that the water supply was the principal cause of the typhoid in 1906-07 may be briefly stated as follows:

1. The distribution of the cases throughout the entire city and their location on the water mains, together with the universal use of city water among those affected.

2. The apparent relation between the time of infection of many cases and known irregularities in the operation of the filter plant; also the occurrence of several cases after east winds had prevailed.

3. The absence of evidence of any other source of infection such as would be indicated by the daily occurrence of a large number of cases among those using milk from one dairy, or infection by the use of raw foods.

The report of these investigations was received in good faith by the waterworks officials and has resulted in the improvements noted at the plant, also the elimination of considerable pollution of the lake at the pumping station, caused by the discharge of a small brook entering the lake opposite the waterworks intake. This brook flows through a thickly populated district receiving considerable drainage and the city officials ordered all wastes kept out of the brook after January 1st, 1908.

SUMMARY.

The result of the investigations at Conneaut are of great interest, as they show the possibility of a false sense of security where a filter plant is provided for the purification of the water supply. The evidence indicates that as a rule the filter plant provides a very satisfactory, potable supply, but that occasionally it does not purify the water when the latter is badly contaminated by the Conneaut River. At the beginning of the investigation, it was apparent that the attendants were not familiar with the proper method of operating a filter plant. There has been a feeling of co-operation on the part of the waterworks officials with the State Board of Health, and a desire to obtain the best possible results at the plant. The results obtained recently have been much more satisfactory.

Among the features that have tended to produce poor results may be mentioned the following:

1. The location of the intake within the sphere of influence of the Conneaut River.
2. Improper methods of operating the filters.
3. Lack of sufficient sedimentation of the coagulated water.
4. Lack of sufficient filtering capacity.
5. Extremely small storage for filtered water at the plant.

During the investigation the second and third of the above conditions have been greatly improved, and there is now contemplated the provision of additional storage for filtered water and also of another filter unit.

Unfortunately, no examination has been made since the improvements at the plant in the winter of 1907, but there is good reason to hope that in the future

much better results will be obtained by the plant on account of the improved methods of operation and the provision of additional sedimentation.

TABLE NO. 5.

Conneaut — Record of Daily Operation.

Month.	Average Daily Consumption "Q" Filtered.	Wash Water.		Alum Used.		Turbidity of Raw Water.
		Gallons.	Per Cent.	Pounds.	Gr. p. Gal.	
1906.						
July	1,116,000	69,000	6.2	170	1.1	.....
August	1,080,000	69,000	6.4	170	1.1	.....
September	1,073,000	69,000	6.4	170	1.1	.....
1907.						
January	.....	.....	.....	.....	.....	.....
February	1,228,000	89,000	7.2	450	2.5	.....
March	1,048,000	149,000	14.2	450	3.0	.....
April	1,078,000	149,000	13.8	450	2.8	.....
May	1,164,000	149,000	12.8	450	2.7	.....
June	1,133,000	99,000	8.7	300	1.8	19
July	1,112,000	99,000	8.9	300	1.8	17
August	1,164,000	99,000	8.4	300	1.8	15±
September	1,146,000	149,000	13.0	400	2.4	38
October	1,122,000	149,000	13.3	400	2.4	47
November	1,116,000	149,000	13.3	400	2.5	94
December	.....	.....	.....	.....	.....	.....
Average	1,121,000	114,000	10.2	339	2.12	38

Wash water applied at 660 gallons per minute.

TABLE NO. 6.

Conneaut — Results of Analyses During Examinations.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	Temp.
	1906	A. M.								
61	6-20	9:30	Forebay	.....	.....	.....	8	.....	88	.....
		P. M.								
69	6-20	3:30	Forebay	.....	.....	.....	24	.....	.....	15
		A. M.								
88	6-21	9:00	Forebay	.....	.....	.....	22	25	94	15
93	6-21	12:00	Forebay	.....	.....	.....	28	35	88	.....
		P. M.								
66	6-20	12:30	Water on filter No. 3.....	1,600	.....	.....	.....	.....	.....	.....
74	6-20	4:00	Water on filter No. 3.....	1,500	0	0	.....	.....	.....	.....
76	6-20	7:30	Water on filter No. 3.....	580	0	0	8	.....	89	.....

TABLE NO. 6 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Temp.
		A. M.								
79	6-21	1:00	Water on filter No. 3.....	75	0	0	.....	.....	.....	.....
81	6-21	4:00	Water on filter No. 3.....	145	0	0	.....	.....	.....	.....
83	6-21	7:30	Water on filter No. 3.....	300	0	0	16	.....	.....	.....
90	6-21	9:30	Water on filter No. 3.....	700	.....	.....	.....	.....	.....	.....
91	6-21	11:00	Water on filter No. 3.....	1,120	.....	.....	.....	.....	.....	.....
		P. M.								
94	6-21	1:00	Water on filter No. 3.....	300	0	0	.....	.....	.....	.....
97	6-21	2:30	Water on filter No. 3.....	75	0	0	.....	.....	.....	.....
		A. M.								
60	6-20	9:00	Lake at intake	.....	.....	.....	8	10±	92	—
		P. M.								
68	6-20	3:00	Lake at intake	350	0	0	12	18	94	16
		P. M.								
65	6-20	12:30	Water on filter No. 1.....	390	.....	.....	8	.....	85	16
70	6-20	4:00	Water on filter No. 1.....	1,290	.....	.....	.....	.....	.....	.....
62-		P. M.								
63-64	6-20	12:30	Average effluents (1-3).....	27	.....	.....	.....	.....	.....	.....
67	6-20	2:30	Clear well	73	.....	.....	0	0	.....	15
72-73	6-20	4:00	Clear well	175	.....	.....	.....	.....	87	16
75	6-20	7:30	Clear well	95	.....	.....	0	0	86	.....
77-78	6-20	8:05	Clear well	270	.....	.....	.....	.....	.....	.....
		A. M.								
80	6-21	1:00	Clear well	150	.....	.....	.....	.....	.....	.....
		A. M.								
82	6-21	4:00	Clear well	18	.....	.....	.....	.....	.....	.....
84	6-21	7:30	Clear well	10	.....	.....	.....	.....	85	16
85-										
86-87	6-21	7:45	Average effluents (1-3).....	28	.....	.....	.....	.....	.....	.....
88	6-21	9:15	Clear well	12	.....	.....	.....	.....	.....	.....
92	6-21	11:00	Clear well	12	.....	.....	.....	.....	.....	.....
		P. M.								
95-96	6-21	1:00	Clear well	25	.....	.....	0	5±	84	15
98	6-21	2:30	Clear well	25	.....	.....	.....	.....	.....	.....
99-										
100	6-21	2:45	Clear well	85	.....	.....	.....	.....	.....	.....
			Average	85	.....	.....	0	<5	85	15
	1906	P. M.								
480	9-11	2:00	Forebay	.....	.....	.....	.....	10±	90	.....
487	9-11	4:10	Forebay	.....	.....	.....	.....	10±	88	.....
		A. M.								
495	9-12	7:00	Forebay	.....	.....	.....	.....	10±	91	.....
502	9-12	11:00	Forebay	.....	.....	.....	.....	10±	88	.....
		P. M.								
478	9-11	1:00	Raw water on No. 3.....	70	0	0	.....	.....	.....	.....
484	9-11	4:00	Raw water on No. 3.....	38	0	0	.....	.....	.....	.....
		Mid.								
491	9-11	12:00	Raw water on No. 3.....	150	0	0	.....	.....	.....	.....
		A. M.								
498	9-12	4:00	Raw water on No. 3.....	900	0	+	.....	.....	.....	.....
497	9-12	8:00	Raw water on No. 3.....	100	0	0	.....	.....	.....	.....
		P. M.								
503	9-12	12:15	Raw water on No. 3.....	86	0	0	.....	.....	.....	.....
		P. M.								
479	9-11	1:00	Settled water top No. 1.....	62	.....	.....	.....	.....	.....	.....
486	9-11	4:00	Settled water top No. 1.....	80	.....	.....	.....	.....	.....	.....
		A. M.								
498	9-12	8:00	Settled water top No. 1.....	50	.....	.....	.....	.....	.....	.....

TABLE NO. 6 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Temp.
504	9-12	P. M. 12:15	Settled water top No. 1.....	125	.....	.....	.....	.....	.....	.....
			Average (479, 485, 498, 504)	72	.....	.....	.....	.....	.....	.....
	1906	P. M.								
477	9-11	1:00	Clear well	24	0	0	....	<5	83	.....
481-2-3	9-11	3:30	Av. filter effluents.....	24	.....	.....	.....	.....	.....	.....
486	9-11	4:00	Clear well	21	0	0	.....	<5	81	.....
488	9-11	7:00	Clear well	17	0	0	.....	.....	.....	.....
489	9-11	8:50	Clear well	30	0	0	.....	<5	85	.....
492	9-11	Md. 12:00	Clear well	50	0	0	.....	.....	.....	.....
494	9-12	A. M. 4:00	Clear well	.....	0	0	.....	<5	78	.....
496	9-12	8:00	Clear well	140	0	0	.....	<5	84	.....
499-500-501	9-12	10:00	Av. effluent from filters.....	16	.....	.....	.....	.....	.....	.....
505	9-12	P. M. 12:15	Clear well	94	0	0	.....	<5	81	.....
508	9-12	1:00	Effluent filter No. 3.....	29	.....	.....	.....	.....	.....	.....
			Average	58	.....	.....	.....	<5	81	.....
	1906	A. M.								
869	12-14	8:00	Raw water — forebay.....	.....	.....	.....	15	70	73	4°
879	12-14	P. M. 3:30	Raw water — forebay.....	.....	.....	.....	.....	55	73	.....
870	12-14	A. M. 9:00	Water top No. 3.....	6,100	0	0	.....	.....	.....	.....
877	12-14	P. M. 2:00	Water top No. 3.....	4,800	0	0	.....	.....	64	.....
881	12-14	8:00	Water top No. 3.....	3,700	0	0	.....	.....	68	.....
884	12-15	A. M. 7:30	Water top No. 3.....	500	0	0	.....	.....	73	.....
871	12-14	A. M. 9:15	Filtered water, clear well....	550	0	0	5	<5	61	.....
875	12-14	P. M. 1:15	Filtered water, clear well....	220	0	0	3	<5	66	4°
882	12-14	8:00	Filtered water, clear well....	0	0	0	3	<5	68	.....
885	12-15	A. M. 8:00	Filtered water, clear well....	0	0	0	6	<5	64	.....
872	12-14	A. M. 9:30	Effluent filter No. 1.....	130	.....	.....	.....	.....	.....	.....
873	12-14	9:30	Effluent filter No. 2.....	350	.....	.....	.....	.....	.....	.....
874	12-14	9:30	Effluent filter No. 3.....	300	.....	.....	8	<5	63	.....
876	12-14	P. M. 12:30	Tap at Cleveland hotel.....	30	0	0	8	<5	64	.....
880	12-14	7:00	Tap at Cleveland hotel.....	65	0	0	5	<5	68	.....
883	12-15	A. M. 6:30	Tap at Cleveland hotel.....	0	0	0	5	<5	60	.....
1124	4-2	1907 A. M. 10:00	Forebay	.....	.....	.....	6	110	75	.....
1125	4-2	10:30	Raw water at pump.....	500	0	0	6	110	74	.....

TABLE NO. 6 — Concluded.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	
		P. M.								
1130	4-2	2:00	Raw water at pump.....	250	0	+	.....	60	74	.....
1135	4-2	8:00	Raw water at pump.....	350	0	0	.....	65	73	.....
			Average	375	.....	.....	.....	80	74	.....
		A. M.								
1126	4-2	11:00	Set. water top filter No. 1...	400	0	0	.....	70	60	.....
		P. M.								
1131	4-2	2:30	Set. water top filter No. 1...	250	0	0	.....	.....	61	.....
1136	4-2	8:30	Set. water top filter No. 1.	250	0	+	.....	.....	54	.....
			Average	310	.....	.....	.....	70	58	.....
		A. M.								
1122	4-2	7:00	Tap at filter pump.....	60	0	0	0	<5	63	.....
1123	4-2	9:00	Tap at filter pump.....	40	0	0	0	<5	56	.....
1127	4-2	11:00	Tap at filter pump.....	24	0	0	0	<5	60	.....
		P. M.								
1129	4-2	1:00	Tap at filter pump.....	12	0	0	0	<5	60	.....
1132	4-2	3:00	Tap at filter pump.....	39	0	0	.....	<5	61	.....
1133	4-2	5:00	Tap at filter pump.....	125	0	0	.....	<5	57	.....
1137	4-2	8:30	Tap at filter pump.....	15	0	0	2	<5	53	.....
			Average	56	.....	.....	2	<5	58	.....
		M.								
1128	4-2	12:00	Tap at Cleveland hotel.....	42	0	0	2	5	58	.....
		P. M.								
1134	4-2	6:00	Tap at Cleveland hotel.....	17	0	0	3	5	60	.....
	1907	A. M.								
1139	4-3	7:30	Raw water at pump.....	475	0	0	.....	80	74	.....
1143	4-3	11:00	Raw water at pump.....	240	0	0	.....	60	73	.....
		P. M.								
1149	4-3	5:00	Raw water at pump.....	115	0	0	.....	70	74	.....
			Average	250	.....	.....	.....	65	74	.....
		A. M.								
1140	4-3	7:30	Set. water top filter No. 1...	375	0	0	.....	80	56	.....
1144	4-3	11:00	Set. water top filter No. 1..	350	0	0	.....	65	57	.....
		P. M.								
1150	4-3	5:00	Set. water top filter No. 1...	325	0	0	.....	60	67	.....
			Average	350	.....	.....	.....	65	60	.....
		A. M.								
1141	4-3	7:30	Tap at filter pump.....	33	0	0	0	<5	56	.....
1142	4-3	9:30	Tap at filter pump.....	23	0	0	0	<5	56	.....
1145	4-3	11:30	Tap at filter pump.....	11	0	+	3	<5	57	.....
		P. M.								
1147	4-3	1:30	Tap at filter pump.....	16	0	0	4	<5	57	.....
1148	4-3	3:30	Tap at filter pump.....	5	0	0	4	<5	56	.....
1151	4-3	5:30	Tap at filter pump.....	32	0	+	3	<5	64	.....
			Average	20	.....	.....	2	<5	58	.....
		A. M.								
1138	4-3	6:00	Tap at Cleveland hotel.....	12	0	0	3	<5	56	.....
		P. M.								
1146	4-3	1:00	Tap at Cleveland hotel.....	6	0	+	4	5±	57	.....

DENNISON AND UHRICHSVILLE.

The cities of Dennison and Uhrichsville are in Tuscarawas County, in the north central part of Ohio. They are both railroad cities and Dennison is the terminal of two divisions of the Pennsylvania Railroad. It contains a large roundhouse and machine shop and the population is very largely composed of the families of railroad employees. The two cities are separated only by the Big Stillwater creek and their interests and occupations are very similar. In 1906 the population of Dennison and Uhrichsville was estimated at 4,500 and 5,200, respectively.

HISTORICAL.

Original Installation.

The waterworks for Dennison and Uhrichsville were first built by the Dennison Water Supply Company in 1888. The pumping plant was located on the shore of the Big Stillwater Creek, about two miles above Dennison and the supply was taken directly from the creek without purification. As originally installed, the plant comprised a cast iron intake, a pumping plant, a storage reservoir located on the divide which separates the valley of the Big Stillwater Creek from Dennison, and a distributing system.

Conditions Leading to Purification.

The drainage area of the Big Stillwater Creek above the intake is estimated at 245 square miles, and comprises a comparatively wild and sparsely settled district. The sides of the stream are of clay earth and precipitous, assuring an active flow and considerable wash of mud into the stream after rains. There are a few farming communities on the watershed, of which the largest is Freeport, with an estimated population of 700, about 18 miles above Dennison. This town has a water supply, and a few sanitary sewers, and there is also a considerable amount of surface washing in the river at this point. The town of Piedmont, with an estimated population of 300, is 22 miles above Dennison and there is a constant danger from pollution of the river at this point.

During the first years of use of the unfiltered creek water deaths from typhoid fever, or other water carried diseases, were unknown, but there was a very serious objection to the use of the river water on account of the very large amounts of suspended matter which it frequently contained. It was for the removal of these suspended matters that the purification plant was installed in 1898.

First Purification Plant.

The first purification plant installed was of the slow sand filter type. Immediately to the west of the pump house, a filter bed was constructed at such a depth that the supply flowed by gravity from the river onto the filter. This was 60′ x 100′ at the bottom, 120′ x 160′ at the top and 14′ deep. The bottoms and sloping sides were covered with concrete masonry to a height of 7 feet. The filtering material comprised 1st, a foot of coarse gravel; 2nd, 6 inches of fine gravel; 3d, 6 inches of coarse sand, and finally one foot of fine, washed sand. The effluent from the filter was collected by a system of underdrains and stored in a clear well 20 feet in diameter by 8 feet deep, from which it was pumped to the distributing reservoir.

The filter did not give satisfactory service as it was found that the sand layers clogged very rapidly and that it was impossible to obtain the necessary quantity of filtered water. The sand filter was abandoned and a new system of

Dennison. — General View of Plant.

gravity mechanical filters, built by the O. H. Jewell Filter Company, installed in June, 1900. The sand and gravel were removed from the old filter, which was used as a settling basin in connection with the new filter plant.

Storage Dam and Intake.

It was found during exceptionally dry seasons that there was an insufficient supply of water in the river, and, in 1904, a concrete storage dam was built in the Big Stillwater Creek, about 8,000 feet below the intake of the Dennison water supply. This dam backs the water about 4 feet above the former low water mark at the intake, and the total storage provided above the dam is about 160,000,000 gallons.

The water at the surface of the river sometimes contained considerably less suspended matter than that at the bottom, and in order to make it possible to vary the point at which water was taken into the intake, with changing depths of water in the river, a new concrete intake tower was built in 1905.

DESCRIPTION OF PLANT.

During the special investigation by the State Board of Health, it will thus be seen that the plant comprised the following features: A storage dam for equalizing the flow of water in the river, a concrete intake tower, a cast iron intake, a forebay, a settling basin formed from the old slow sand filter, low and high service pumps, a clear well and a distributing reservoir.

Intake.

The intake is a concrete tower, located near the center of the stream. It contains screened openings and sluice valves, so placed that it is possible to take water into the tower from three different levels, one at the bottom, one intermediate and one near the surface of the water in the river. From the tower a 24-inch cast iron pipe, 190 feet long, leads to the forebay, which is brick lined, and about 5 feet in diameter.

Pumps.

The pumping plant comprises three units, any one of which may be used to pump either filtered or raw water. The pump house contains one horizontal duplex Worthington pump of 2 million gallons capacity; one horizontal duplex Holly pump of 2 million gallons capacity, and one horizontal duplex Fairbanks-Morse pump of 3 million gallons capacity. The Holly pump is generally used on high service to the reservoir, and either the Worthington or Fairbanks-Morse pump on the low service to the filters.

Coagulating System.

Coagulant. The coagulant used is the Natrona brand of aluminum sulphate, obtained from the Pennsylvania Salt Manufacturing Company of Philadelphia, Pa.

Solution Tanks. In the east end of the filter house are the tanks for dissolving and storing the coagulant. These are two wooden tubs, each 7.0 feet in diameter by 14 feet high, with a capacity of 4,000 gallons each.

Application of Coagulant. From the storage tanks a 1-inch lead pipe carries the solution to a regulating tank which contains a float valve, by which a constant depth of solution is maintained. The discharge from the regulating tank is also a 1-inch lead pipe, and a small globe valve is provided in this line to regulate the rate of application of the solution.

It is possible to apply the coagulant at two points, one at the entrance to the large coagulating basin, and the other at its outlet. It is thus possible to secure a secondary application of the coagulant in the water before it is pumped onto the filters, and this division of coagulant is used particularly during periods of high turbidity in the river water.

Coagulating Basin.

The coagulating basin is constructed from the old slow sand filter. It is 81 feet by 121 feet at the bottom, and its sides slope 1½ to 1. Its total available depth is 5.5 feet. Deducting the area occupied by the clear well the net capacity of the coagulating basin is 460,000 gallons, which at the ordinary rate of pumping, 1,400 gallons per minute, gives a coagulating period of 5½ hours.

A small compartment is constructed in the end of the coagulating basin near the forebay. The raw water flows by gravity from the forebay into this small compartment, where it receives the first application of coagulant. This small compartment discharges through an 18-inch cast iron pipe which extends to the opposite end of the coagulating basin and discharges near the bottom of the basin. A small compartment 10 feet wide is formed by a baffle in this end of the coagulating basin, and it contains a sump well 2' x 2'|x 2', which well contains the suction for the sludge pump used to clean the basin. This pump is of the Emerson type, and has a capacity of one million gallons in 24 hours. The discharge from the coagulating basin is through a valve into another small compartment 6 feet square opposite the inlet. This compartment contains the suction of the low service pumps by which the water is lifted through the small settling tanks beneath the filters where there is an additional coagulating capacity of 46,000 gallons or 30 minutes.

Filters.

The filter plant comprises four wooden tanks each 15 feet in diameter with a total area of 707 square feet or .01625 acre. The nominal capacity of the plant is 1,600,000 gallons in 24 hours.

Detail drawings showing the essential features of the filters are shown on Plate V. It will be seen that the strainer system comprises a manifold of wrought iron pipe into which perforated brass strainers are screwed at 6-inch intervals. Directly on top of the strainer system is placed the filtering material which consists of 48 inches of sand having an effective size of 0.48 m. m. and a uniformity coefficient of 1.3. The wash water is applied by a connection to the force main and mechanical rakes are provided in each filter to assist in washing.

No automatic rate controllers nor loss of head gauges are provided.

Storage of Filtered Water.

Clear Well. The effluent from the filters is collected in a flume and flows over a weir into the clear well, which is a covered concrete tank approximately 22.8 feet in diameter and 18 feet deep, holding 54,000 gallons. Its available depth, however, is 16 feet, which gives a working capacity of 48,000 gallons or 34 minutes at the usual rate of pumping.

Distributing Reservoir. From the clear well the water is pumped through a 12-inch cast iron force main, 2,900 feet long to the distributing reservoir located on the ridge dividing Dennison and Uhrichsville from the valley of the Stillwater Creek. The reservoir is an open basin of 3,700,000 gallons capacity, and its sides and bottom are covered with cemented brick pavement. No provision is made for cleaning the reservoir but the water is drawn down at least once a year and the sides scraped to remove growths, which generally accumulate during the warm season.

The static pressure at the high service pumps is 100 pounds per square inch which is increased to 107 pounds per square inch when the pumps are in service.

EXAMINATIONS.

During the special investigation by the State Board of Health, the water purification plant at Dennison has been visited five times: on May 21st, July (4-6), 1906, January (2-3), April (16-18), 1907, and January 29th, 1908. Regular examinations were made except on the first and last visits, when the plant was inspected.

OPERATION.

When the plant is in operation, water flows by gravity through the intake into the forebay, and thence into the small compartment in the coagulating basin where the alum is applied. From this compartment it flows by gravity into and through the coagulating basin and thence into the suction well of the raw water pumps by which it is forced through the settling tanks and onto the filters. The effluent from the filters is collected in the clear well and is pumped to the distributing reservoir from which it flows by gravity into the mains.

The plant is run during the entire day at nearly its maximum capacity. The operation is accomplished under two shifts from 6:00 a. m. until 6:00 p. m. and is in charge of one engineer during the day and an engineer and fireman during the night. It is the custom to operate the plant at somewhat faster rates during the night than during the day.

Average Daily Consumption.

The average number of gallons pumped daily at Dennison and Uhrichsville from June, 1906 to September, 1907, was 1,941,000 gallons. This quantity is in excess of the guaranteed capacity for the plant, 1,600,000 gallons, and it was necessary to operate the filters at greater rates than was intended when the plant was constructed. From the daily records it will be seen that an average quantity of 174,000 gallons was used daily to wash the filters, so that the average actual consumption was 1,767,000 gallons.

Methods of Applying Coagulant.

In preparing the alum solution it is the custom to place the charge, generally about one-half barrel, in the tank, add the water and stir the mixture until the coagulant is dissolved. But one tank has been used and it is necessary to prepare a new solution as the tank becomes empty.

There is a considerable variation in the quantity of coagulant applied, as it is necessary to increase the coagulant at such times as the river is turbid. From the daily records it will be seen that the average quantity applied during the investigation was 1.2 grains per gallon. During July, 1907, the river was unusually turbid, and the average quantity used daily during this month was 2.7 grains per gallon. On the month following, August, 1907, the river was clearer than at any other time, as is shown by the average turbidity of but 29 parts per million, and during this month but 0.4 grain of alum per gallon was used.

There are two methods in use for applying the coagulant, as all of it may be introduced into the first compartment at the entrance of the coagulating basins, or the solution may be divided into two parts, one of which is applied as above stated, and the other at the outlet of the basin from which the water is pumped into the small compartments beneath the filters. In this manner the coagulating

periods may be varied from one of 6 hours to one of 5½ hours followed by a second period of one-half hour. It is generally the custom to apply all of the solution in the first compartment, allowing 6 hours coagulation, except during periods of high turbidity in the river, when a secondary application is used also.

Coagulating Basin.

During the first examination in July, 1906, the coagulating basin was not in use, and water flowed from the forebay into the first small compartment and thence into the small compartment now used as a suction well, so that the period of coagulation allowed was not greater than one hour. During this examination it was suggested that much more economical results and better efficiencies would be obtained by repairing the basin, which was done in the following months. The total cost of the repairs, including the pipe through the basin, the building of the baffle, and cleaning of the basin was approximately $450.00. An Emerson sludge pump has also been provided with which the basin is easily cleaned when necessary.

In general it may be said that the operation of the basin requires very little attention, but since its use from the fall of 1906, there has resulted much greater ease and economy in operating the filter plant, as a less load has been placed on the filters.

Filters.

Rate of Filtration. From the daily records it will be seen that the average quantity of water filtered has been 1,941,000 gallons, and as the total area of the filters is .01625 acre, the corresponding average rate of filtration is 120 million gallons per acre per day. No allowance is included in this estimate for time lost in washing the filters.

During each of the examinations several measurements of the rates of filtration were taken and it was found that, immediately after washing, the filters were operated at very high rates, occasionally as great as 175 million gallons per acre per day. These high rates were necessary on account of the small storage provided in the clear well. It was the custom to wash all of the filters at once, and as the filtered water pump was operating at the usual rate, it was necessary to maintain the quantity filtered with three filters for one hour the same as had been filtered by four before the washing was started. During this first examination it was advised that better results would be obtained by operating the filters slower after washing, which would require either that the filtered water pump be slowed down when the filters were washed, or that about one hour be allowed between washing the different filters, so that the filters would not have to operate at excessive rates. Since this examination it has been the custom to slow down the filtered water pump during washing.

During each of the examinations the filters have been run at higher rates than the average as but three units were in service. On the first examination it was requested that the filters be run at the rate that generally maintains during the night, on which account but three filters were used, while on the following examinations one filter was out of service owing to repairs. During the examination of January 3rd, the average rate of filtration was 126 million gallons per acre per day, while during the examination of April 16th, the average rate was 143 million gallons per acre per day.

In general it may be said that little attempt is made to operate the filters at a constant rate and that somewhat better result would doubtless be obtained if automatic rate controllers were provided.

Washing. In the absence of loss of head gages it is impossible to tell when the filters are dirty, but it is the custom to wash them at regular intervals, generally early in the morning during the night run, and if necessary, again in

the afternoon about twelve hours later. It is seldom necessary to wash them more than twice in 24 hours. As the wash water is applied from a connection to the force main, its rate of application varies with the degree of opening of the valve and several measurements of the rate have shown considerable variation. The average rate of washing is approximately one vertical foot per minute for twenty minutes.

The average quantity of wash water used daily during the investigation has been 174,000 gallons or 8.9 per cent. of the total quantity of water filtered. The maximum number of filters washed as shown on the daily records was on August 24th, 1906, before the coagulating basin was in service; twenty-eight filters were then washed and approximately 700,000 gallons of water used or 37 per cent. of the total quantity of water filtered. The turbidity of the river, as shown on the daily records, was then 4500 parts per million.

Growths in Filters.

About three weeks previous to the examination of January 3rd, 1907, sand leaked through one of the filters into the clear well and before discovered it had been sucked up into the filtered water pump, cutting out the plungers and cylinders. The damage done was so great that it was necessary to replace the plungers in the pump and also to rebore the cylinders. An examination into the cause of this leakage of sand developed the fact that the strainer system was clogged by a growth which had closed the majority of the perforations, so that, when the wash water was applied, the bands of which the sides of the strainers were composed had broken. In the absence of gravel above the strainers these breaks provided a ready means of passage of the sand from the filters through the effluent piping into the clear well.

A further examination revealed the fact that this growth, which was found to be one of the Bryozoa, had developed throughout the entire plant, in the clear well and particularly in the filters, where it had attached itself to the agitators and the sides of the tanks as well as in the strainer cups. The growth in the strainers was the most serious, as it was found necessary to remove all of the bands in each filter in turn and to replace them. Many of the tops of the strainers also had to be replaced.

The leakage from the different filters did not occur at the same time, but from each filter in succession, and were repaired in turn as was found necessary. During the examinations of January and April, 1907, but three filters were in service, as one unit was being overhauled and repaired.. During this time it was necessary to operate the filters at unusually high rates and it was fortunate that the large coagulating basin had been placed in service, as otherwise it would have been impossible to obtain a sufficient quantity of water through the filters to meet the demands of the consumption.

In making the repairs to the filters it was necessary to purchase 2,200 screens at 6 cents each, and also a large number of tops. These, together with the necessary labor, required a total expenditure of nearly $500.

During the examinations of January and April, 1907, it was advised that future leakage of sand could be largely prevented by providing a layer of screened gravel over the strainers, which gravel would also cause a better distribution of the wash water. It was, however, found impossible to obtain suitable material locally, and the sand was replaced in the filters directly on the strainers.

It was also advised during these examinations that in order to avoid future trouble from the growths they should be removed, for which purpose the use of copper sulphate was suggested. In the spring of 1907 the filters were treated with copper sulphate, one pound of which was applied to each filter. This corre-

sponds to 17 parts per million. No beneficial results were observed from this treatment and it is to be expected that future trouble from these growths will recur unless some satisfactory treatment is applied. During the inspection of January 29th, 1908, it was advised that the dose of copper sulphate be considerably increased and it is reasonable to suppose that the proper use of this chemical would destroy the growth.

CHARACTER OF RAW WATER.

During each of the examinations samples of the raw water were obtained from the forebay at the end of the intake. Unfortunately for the purposes of this investigation, no examinations were made at the Dennison plant during such times as the river was very dirty.

The analyses indicate that there was little change in the character of the river water during the several examinations. From the daily records it is apparent that the river is frequently very turbid, and the average turbidity shown is 316 parts per million. During 1907 the river was more turbid during July than any other month, the effect of which on the operation of the plant is shown by the unusually large quantity of coagulant necessary and also by the increased percentage of wash water.

It will be noted that chemically the river contains but very little dissolved color and that it is of medium hardness.

The results of the examinations for coli are particularly significant, as the colon bacillus was found in but few samples, and then only in 100 c. c. portions. The total bacterial content covers a considerable range, but the total number of becteria is less than has been found in most of the other surface waters in Ohio.

The evidence indicates that the water in the Big Stillwater Creek at Dennison is frequently very turbid and always carries objectionably large quantities of suspended matter. The absence of pollution on the watershed is indicated by the coli results, and it is apparent that the satisfactory purification of the river water requires only the removal of objectionable suspended matter and not a high bacterial efficiency.

EFFICIENCIES.

Guarantee.

The contract covering the construction of the filter plant contains the guarantee that the filtered water shall be bright and clear and free from suspended matter visible to the naked eye; that there shall be an average bacterial reduction of 97 per cent. when the raw water contains more than 7,000 per c c. and that when the raw water contains less than 7,000 per c. c. the reduction shall be such that not more than 200 shall be found in the filtered water.

Methods of Applying Coagulant.

The alkalinity determinations of the filtered water indicate that there was less alum applied at the end of the run-off of a solution tank than at the beginning. This is undoubtedly due to the absence of agitation in the tanks, which generally hold twelve hours supply of coagulant, so that as the stronger solution settles to the bottom that which is last applied is weaker than the average. There is also some variation in the quantity applied when a new charge is dissolved. In general it may be said, however, that the methods of applying the coagulant have proven satisfactory, and although there is a slight variation in the quantity applied, this is largely equalized by the considerable storage in the coagulating basin.

Coagulating Basin.

During the examination of April 17, 1907, samples of water were obtained from the outlet of the settling or coagulating basin, and their analysis indicates a removal of about 50 per cent. of bacteria by the basin. In the daily records is shown the turbidity of the water as it leaves the basin, and it is apparent that there is an average removal by the basin of approximately 58 per cent. of the turbidity of the treated water. On but two months during 1907 has the turbidity of the water applied to the filters been less than 50 parts per million, which would indicate that greater economy of wash water would occur with the use of larger quantities of coagulant.

In general it may be said that very satisfactory results have been obtained by the coagulating basin, and as previously noted, the capacity of the filters has been largely increased since the basin has been in use. Although the theoretical period of coagulation in the basin is 5.5 hours, the actual period is considerably less, as the displacement beyond the first baffle is not very good. The efficiency of the basin could be improved by providing two more transverse baffles.

Filters.

Rates of Filtration. The evidence indicates that better results would be obtained by the filters if automatic rate controllers were provided, as there is a tendency to operate the filters at very high rates, particularly after washing. Owing to repairs it was necessary to operate the filters at unusually high rate during the examinations, so that the bacterial efficiencies obtained are probably not as good as would have been the case if the filters had been run more slowly.

Washing. During each of the examinations the sand in the filters has been found clean and well washed, but it is probable, however, that there would be a saving in the use of wash water if gravel were provided above the strainer systems. This would permit of a better distribution of the wash water. It has been necessary to use less wash water since the coagulating basin has been in service, as there has been a less load placed upon the filters.

Bacterial Removal. The results obtained during the first examination of the plant indicate a satisfactory removal of bacteria, although the filters were operated at high rates. The poor removals during the examination of January 3d, 1907, were probably due to the fact that many of the strainers in the filters were clogged causing uneven rates of filtration. The average rates were also high. The wholesomeness of the water, however, is indicated by the absence of coli.

From the fact that less bacteria were found in the effluents from the filters than in the samples taken from the pump it would appear that the removals previous to the examination were not as good as obtained during the test. Although satisfactory bacterial removals were obtained during the examination of April 17th, 1907, it is apparent that the efficiencies obtained immediately previous to the examination were not as good, a fact which is indicated by the comparatively large numbers of bacteria in the samples from the Hyatt Hotel, one of which samples also contained coli in 100 c. c. This is the only sample of filtered water obtained during the examinations in which coli were found even in 100 c. c .portions.

SUMMARY OF RESULTS OF INVESTIGATION.

The examinations of the water of the Big Stillwater Creek at Dennison indicate that, while it is always objectionably turbid, it contains but little evi-

dence of pollution. Its satisfactory purification requires the removal of objectionable suspended matters and not a high bacterial efficiency.

Although the coagulating basin is unusually large and permits of a satisfactory preparation of the water for the filters, its efficiency could be increased by baffles. These will probably be added in the spring of 1908.

The efficiencies obtained by the filters during the examinations of 1907 have been effected by growths in the strainers which have necessitated high rates of filtration. Until this growth is eliminated the trouble experienced in the winter of 1906-7 will be repeated. Although occasionally the filtered water has contained larger numbers of bacteria than are desirable, yet the absence of coli during the examinations would indicate that the water supply has been potable.

During the fall of 1907 there were reported about thirty-five cases of typhoid fever in Dennison and Uhrichsville, which cases have been carefully investigated by the superintendent of the water company. But one death was reported, and that from typhoid pneumonia. One striking feature was the prevalence of the disease among children, as but four of those affected were over 20 years of age. An examination into possible infection shows that in many instances well water had been used, and that there was frequently a near source of pollution to the wells. The occurrence of such a large percentage of cases among children would indicate that the milk supply was a possible source of infection, although there was not a prevalence of cases among the customers of any one dairy.

In conclusion it should be stated that while occasionally the bacterial removals obtained at the filter plant are not as great as is considered desirable, yet the absence of pollution on the watershed as indicated by inspection and also by the absence of coli, indicate that the water supply at Dennison is potable. Until the fall of 1907 there were but very few cases of typhoid fever reported in Dennison, and there is no reason to suspect that the several cases reported at that time were due to the water supply.

COST OF INSTALLATION.

In the following table is shown the cost of some of the main features of the purification plant. The cost of the distributing system, reservoir and pump house is not included, as they were constructed under a joint contract and it is impossible to determine their cost.

Storage dam		$7,000
Intake		12,000
Settling basin		8,000
Filters and building		35,000
Clear well		1,500
Pumps		14,200
Fairbanks	$1,200	
Holly	7,500	
Worthington	5,500	
Total cost		$77,700

The total cost of the entire plant is not far from $300,000.

COST OF OPERATION.

The principal items incurred by the operation of the water purification plant during 1906, not including taxes nor repairs and maintenance of distribution system, are shown in the following table. The water company operates its own

mine from which it obtains all the coal used at the plant. The average cost of mining the fuel is included in the following table:

Labor		$2,580
Two engineers	$1,800	
One fireman	780	
Fuel (average cost)		4,000
Coagulant (121,155 pounds)*		1,755
Total cost		$8,335
Total number of gallons pumped		708,465,000
Average cost per million gallons		$11 91
Labor per million gallons	$3 63	
Fuel per million gallons	5 64	
Coagulant per million gallons*	2 47	

Interest on bonds equals $7,500, which increases the cost per million gallons $10.58, making a total of $22.49, per million gallons, not including the cost of maintaining an office and the distributing system.

*Includes cost of alum purchased; see daily records for average quantity actually used.

TABLE NO. 7.

Dennison — Record of Operation.

Month.	Average Daily Consumption "Q" Filtered.	Wash Water.*		Alum Used		Turbidity.	
		Gallons.	Per Cent.	Pounds.	Gr. p. Gal.	Raw Water.	Out. of Basin.
1906.							
June	1,787,000	134,000	7.5	207	0.8	.....	.....
July	1,752,000	172,000	9.8	308	1.2	.....	.....
August	1,896,000	333,000	17.5	662	2.4	1,498	.....
September	1,922,000	208,000	10.8	313	1.1	142	.....
October	2,080,000	140,000	6.7	190	0.6	63	.....
November	.....	.....	.....	.....	.....	.....	.....
December	.....	.....	.....	.....	.....	.....	.....
1907.							
January	1,917,000	199,000	10.3	400	1.4	222	63
February	1,915,000	156,000	8.1	178	0.6	49	31
March	1,973,000	179,000	9.0	316	1.1	260	83
April	1,928,000	144,000	7.5	303	1.1	131	56
May	1,962,000	125,000	6.3	435	1.5	129	56
June	2,080,000	168,000	8.0	414	1.3	268	92
July	1,970,000	244,000	12.4	766	2.7	802	121
August	2,114,000	134,000	6.3	130	0.4	29	21
September	1,877,000	104,000	5.5	234	0.8	203	102
Average	1,941,000	174,000	8.9	347	1.2	316	69

* Wash water applied at 1,300 gallons per minute.

TABLE NO. 8.

Dennison — Results of Analyses During Examinations.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	
	1906	A. M.								
125	7-4	8:00	Raw water	800	0	0	4	65	.....	.....
131	7-4	11:00	Raw water	650	0	0	4	75	108	.....
		P. M.								
133	7-4	2:00	Raw water	275	0	0	4	.....	.....	.....
139	7-4	4:30	Raw water	650	0	0	8	90	96	.....
142	7-4	8:15	Raw water	500	0	0	.....	.....	.....	.....
		Md.								
143	7-4	12:00	Raw water	1,700	0	0	.....	.....	88	.....
			Average	460	.....	.....	5	77	96	.....
		A. M.								
126	7-4	8:30	Filter pump (1)	22	0	0	0	0	91	.....
132	7-4	11:30	Filter pump	48	0	0	2	0	100	.....
		P. M.								
138	7-4	8:00	Filter pump	25	.....	.....	2	0	98	.....
141	7-4	8:00	Filter pump	.....	0	0	.....	.....	.....	.....
		Md.								
144	7-4	12:00	Filter pump	20	0	0	4	0	95	.....
			Average	29	.....	.....	3	.....	96	.....
		A. M.								
127	7-4	9:45	Effluent No. 1	38	0	0	.....	.....	.....	.....
128	7-4	9:45	Effluent No. 2	16	0	0	.....	.....	.....	.....
129	7-4	9:45	Effluent No. 3	55	0	0	.....	.....	.....	.....
130	7-4	9:45	Effluent No. 4	23	0	0	.....	.....	.....	.....
		P. M.								
134	7-4	2:00	Effluent No. 1	6	0	0	.....	.....	.....	.....
135	7-4	2:00	Effluent No. 2	12	0	0	.....	.....	.....	.....
136	7-4	2:00	Effluent No. 3	55	0	0	.....	.....	.....	.....
137	7-4	2:00	Effluent No. 4	49	0	0	.....	.....	.....	.....
			Average	33	.....	.....	.....	.....	.....	.....
140	7-4	5:00	Effluent, clear well	80	0	0	2	0	91	.....
		A. M.								
145	7-5	4:00	Raw water	700	0	0	.....	.....	90	.....
151	7-5	7:20	Raw water	190	.....	.....	8	65	98	.....
153	7-5	11:15	Raw water	—	—	—	4	.....	.....	.....
		P. M.								
160	7-5	5:00	Raw water	180	0	0	4	.....	100	.....
163	7-5	8:00	Raw water	550	.....	.....	.....	.....	.....	.....
		A. M.								
166	7-6	7:40	Raw water	65	.....	.....	.....	.....	.....	.....
			Average	340	.....	.....	5	.....	96	.....
	1906	A. M.								
146	7-5	4:00	Filter pump (1)	11	0	0	4	0	85	.....
152	7-5	7:25	Filter pump	24	.....	.....	6	0	90	.....
154	7-5	11:30	Filter pump	170	.....	.....	3	0	.....	.....

(1) Samples taken from tap at high service pump.

TABLE NO. 8 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Temp
		P. M.								
155	7-5	1:00	Filter pump	42	.....	.....	.....	.....	.....	.....
157	7-5	3:00	Filter pump	28	.....	.....	.....	.....	.....	.....
159	7-5	5:00	Filter pump	20	.....	.....	4	0	92	.....
161	7-5	6:00	Filter pump	50	.....	.....	.....	.....	.....	.....
162	7-5	7:00	Filter pump	80	.....	.....	.....	.....	.....	.....
164	7-5	8:00	Filter pump	42	.....	.....	.....	.....	.....	.....
		A. M.								
165	7-6	7:30	Filter pump	1	.....	.....	.....	.....	.....	.....
			Average	47	.....	.....	4	.....	89	.....
		A. M.								
147	7-5	7:15	Effluent No. 1	50	.....	.....	.....	.....	.....	.....
148	7-5	7:15	Effluent No. 2	40	.....	.....	.....	.....	.....	.....
149	7-5	7:15	Effluent No. 3	70	.....	.....	.....	.....	.....	.....
150	7-5	7:15	Effluent No. 4	170	.....	.....	.....	.....	.....	.....
		P. M.								
158	7-5	3:30	Effluent No. 2	60	.....	.....	.....	.....	.....	.....
156	7-5	1:30	Reservoir	90	0	0	8	0	92	.....
	1907	A. M.								
902	1-3	8:00	Raw water	6,100	0	0	15	80	70	.....
		M.								
908	1-3	12:00	Raw water	10,800	0	+	15	85	70	6.5
			Average	8,500	.....	.....	15	83	70	.....
		A. M.								
901	1-3	8:00	Set. water top of filter No. 1	4,700	0	0	.....	35	45	.....
904	1-3	10:30	Set. water top of filter No. 1	3,400	0	0	15	35	49	.....
		P. M.								
910	1-3	3:00	Set. water top of filter No. 1	3,800	0	0	.....	40	53	.....
			Average	4,000	.....	.....	15	37	49	.....
		A. M.								
905	1-3	11:00	Effluent filter No. 1	700	.....	.....	8	<5	50	.....
906	1-3	11:00	Effluent filter No. 3	650	.....	.....	.....	.....	.....	.....
907	1-3	11:00	Effluent filter No. 4	650	.....	.....	.....	.....	.....	.....
			Average	765	.....	.....	8	<5	50	.....
900	1-3	9:00	Filtered water from pump	810	0	0	8	<5	47	.....
908	1-3	10:30	Filtered water from pump	2,650	0	0	8	<5	47	7
		P. M.								
909	1-3	1:00	Filtered water from pump	.....	0	0	8	<5	50	.....
911	1-3	3:45	Filtered water from pump	1,410	0	0	10[1]	<5	51	.....
			Average	1,600	.....	.....	9	<5	49	.....

[1]Filtered.

TABLE NO. 8 — Concluded.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	
	1907	A. M.								
1152	4-17	8:30	Raw water from creek.....	2,100	0	+	10	28	93	.....
		P. M.								
1157	4-17	1:00	Raw water from creek.....	2,500	0	+	8	26	94	.....
1161	4-17	5:00	Raw water from creek[4].....	1,900	0	+	.....	.....	94	.....
			Average	2,200	.....	.....	9	27	94	.....
		A. M.								
1153	4-17	8:30	Set. water top filter No. 2[1].	1,400	0	+	.....	18	88	.....
		P. M.								
1158	4-17	1:00	Set. water top filter No. 2..	800	0	+	.....	.....	88	.....
1162	4-17	5:00	Set. water top filter No. 2..	1,000	0	+	.....	.....	88	.....
			Average	1,100	.....	.....	.....	18	88	.....
		A. M.								
1154	4-17	8:30	Filtered water — clear well..	125	0	0	5	<5	88	.....
1155	4-17	10:30	Filtered water — clear well..	100	0	0	3	<5	87	.....
		P. M.								
1159	4-17	1:00	Filtered water — clear well..	65	0	0	5	<5	87	.....
1160	4-17	3:00	Filtered water — clear well..	160	0	0	5	<5	87	.....
1163	4-17	5:00	Filtered water — clear well..	160	0	0	5	<5	87	.....
1164	4-17	10:00	Filtered water — clear well..	260	0	0	5	<5	84	.....
			Average	160	.....	.....	5	<5	86	.....
		P. M.								
1156	4-17	12:30	Tap at Hyatt hotel.....	400	0	+	8	5	80	.....
		A. M.								
1166	4-18	7:00	Raw water	2,900	0	+	8	26	96	.....
1172	4-18	11:00	Raw water	2,900	.....	.....	.....	26	95	.....
			Average	2,900	.....	.....	8	26	95	.....
1170	4-18	7:00	Set. water outlet of basin...	540	0	0	.....	15	87	.....
1173	4-18	11:00	Set. water outlet of basin[3]...	1,800	0	0	.....	18	86	.....
			Average	1,170	.....	.....	.....	17	87	.....
1167	4-18	7:00	Set. water top filter No. 2[2].	1,300	.....	.....	.....	40±	78	.....
1174	4-18	11:00	Set. water top filter No. 2[2].	1,800	0	0	.....	.....	80	.....
			Average	1,550	.....	.....	.....	30	79	.....
	1907	P. M.								
1165	4-18	3:00	Clear well	3	0	0	5	<5	84	.....
1168	4-18	7:00	Clear well	70	0	0	2	<5	77	.....
1171	4-18	9:00	Clear well	100	0	0	2	<5	80	.....
1175	4-18	11:00	Clear well	210	0	0	3	<5	78	.....
			Average	120	.....	.....	3	<5	79	.....
		A. M.								
1169	4-18	6:00	Tap at Hyatt hotel.....	370	0	0	8	5—	80	.....

[1]No coagulation visible.
[2]Increased alum at 4:45 A. M.
[3]Coagulation visible.
[4]Temperature, 5.5°C.

ELYRIA.

Elyria is a city of about 18,000 inhabitants, situated on the Black River in Lorain County about nine miles from Lake Erie. Although essentially a residential town, the city contains a considerable number of manufacturies.

HISTORICAL.

The waterworks were first installed in 1879, using as a source the west branch of the Black River, from which water was pumped directly without purification. As the river received a great deal of drainage from farm lands and also all of the sewage of Oberlin, it was very unsatisfactory both from a physical and sanitary standpoint; moreover, during the dry seasons of the year — even at the comparatively low rate of consumption then prevailing — it was with difficulty that a sufficient quantity of water was obtained. It will thus be seen that the supply was unsatisfactory as regards both quality and quantity. Although Lake Erie was nine miles distant from the center of Elyria, it offered the only available source where an abundant supply could be obtained at reasonable cost, and it was from this lake that the new supply was taken.

Necessity for Purification.

The new waterworks were built by the city of Elyria in 1903. The plant containing the filters and pumps is located on the shore of Lake Erie, about two and one-half miles west of the mouth of the Black River, at a point well removed from any local contamination. The nearest sources of pollution are the Black River, two and one-half miles to the east, into which the sewage from Oberlin, Elyria, and the greater part of that from Lorain, is emptied; and to the west, Beaver Creek, the mouth of which is about two miles from the intake and which carries a small quantity of sewage from the stone quarries at North Amherst. In general it may be said that the lake water at the intake of the Elyria waterworks seldom contains more than a trace of pollution from domestic wastes and that filtration is necessary more for the removal of inorganic suspended matters than for a bacteriological purification.

DESCRIPTION OF PLANT.

As originally installed, the plant consisted of the intake, raw and filtered water pumps, two boilers, two coagulating basins, four gravity mechanical filters together with the necessary coagulant tanks, and the clear well. The filters, pumps and boilers are housed in separate rooms of a substantial brick building. During this investigation there have been added three filters and a large concrete settling or coagulating basin. (See Plate VI.)

Intake and Raw Water Pumps.

The intake consists of a wooden crib, 1,500 feet from the shore of the lake, from which extends a 24-inch cast iron pipe to a forebay, 30 feet deep and 15 feet in diameter. The total depth of water at the crib is 28 feet but the suction pipe is turned up so that water is actually taken from a point about 14 feet above the lake bottom. There is no provision for taking water at any other level.

The low service pumps by which water is taken from the forebay, consist of a 3 million gallon compound duplex pump installed in 1904 and a 5 million gallon compound duplex pump, installed in March, 1905. The suction lift to these pumps is about 11 feet while the total lift to the filters is approximately 35 feet.

Coagulants.

It was the intention in installing the plant to use either alum or lime and copperas treatment for coagulation, and the specifications stated that the average cost per million gallons for coagulants should not exceed $2.00, estimating the cost of the copperas at $8.50 per ton. The coagulants used since the plant was installed have been copperas, obtained from the American Steel & Wire Company, and Marion lime, obtained from a local dealer in Lorain.

Method of Applying Coagulants.

The coagulant solutions are prepared in a small brick house near the pump room. It contains four tanks, two for lime water and two for the copperas solution. A small wooden tank of about 300 gallons capacity is provided to slake the lime. The outlet of the slaking tank is screened and leads to the storage tanks. The storage tanks for the lime are each 10.6′ x 10,6′ x 9′ deep, and hold 7,570 gallons. The storage tanks for the copperas are 10.6′ x 5.3′ x 9′ deep with a total capacity of 3,780 gallons, or one-half that of the lime tanks. Ball-cock tanks are provided to regulate the rate at which the solutions are applied. The discharge from these tanks is controlled by specially designed globe valves with indicators showing their degree of opening. The solutions are applied by a pump of a special design, obtained from the Marsh Pump Works of Battle Creek, Mich. The lime end of the pump is of cast iron, while the end handling the copperas solution is of brass, the cylinder of the latter being one-half the size of that for handling the lime, which is 6 inches in diameter. The suctions of the pump are provided with funnels which receive the discharge from the ball-cock tanks. The discharge pipes are of wrought iron and the copperas solution is pumped into the raw water force main at a point about 30 feet in advance of the lime water.

Since the last examination, it is learned that a change has been made in the method of applying the copperas. A galvanized iron tank, 15 inches in diameter by 4 feet high, has been provided, containing in the bottom a brass screen and a connection for applying water from the force main. An overflow is also provided just below the top of the tank, and carries the solution to the funnel in the suction of the coagulant pump.

The method of operation consists in dumping the charge of copperas into the top of the tank at regular intervals, and its solution is effected by the stream of water flowing upward through the tank and discharging by means of the overflow into the suction of the coagulant pump. No examination has been made at Elyria since this method of feeding was installed.*

Coagulating Basins.

Original Installation. The coagulating tanks as originally installed consisted of two wooden tubs, each 30 feet in diameter by 15 feet high, with a total capacity of 159,000 gallons. The inlets to the basins were of 10-inch cast iron and entered the sides of the tanks about 3 feet from the bottom; while the outlets, also of 10-inch cast iron were located about 3 feet below the top. There were no baffles provided, and the inlets terminated in elbows turned horizontally at right angles to the diameters of the tanks. A gage in the pump room indicated the actual height of water in the tubs and an automatic electric alarm attached to this gage signaled when the tanks were full.

Additions to Coagulating Tanks. A new coagulating basin of concrete was built during the summer of 1907 and is located on the high ground immediately

*Note — This apparatus is satisfactory for applying small quantities of copperas.

to the west of the filter house. It is a concrete basin 150 feet in diameter at the top, the side slopes being approximately 1½ to 1, while the maximum depth of water in the basin is 12 feet. Its capacity when full is 1½ million gallons. A vertical reinforced concrete baffle through the center of the basin divides it into two compartments of equal size. Into one of these compartments the 16-inch cast iron inlet discharges at a point 4 feet above the bottom near the baffle, while in the other compartment the 16-inch cast iron outlet is located about 4 feet above the bottom and also near the baffle. An opening 2 feet square, about 4 feet from the bottom is provided through the baffle wall between the two compartments. The actual distance traveled by the water is about 300 feet. The examinations made during the special investigation were completed before the new coagulating basin was in service.

Filters.

Capacity of Plant. The filter plant contains not only the 4 original filters having a combined area of 707 square feet, but also three additional concrete units that have been constructed since 1903 and have a total area of 784 square feet. The total filtering area available is 1,491 square feet (.0343 A), and the nominal capacity of the filter plant at 125,000,000 gallons per acre per day is 4,280,000 gallons.

Original Installation. From the two wooden coagulating tanks the water flowed by gravity onto the filters, which are located in the filter building at approximately the same elevation as the tanks. The original installation was of four filters, each 15 feet in diameter and having a total area of 707 square feet, or 0.01625 acre. The filter proper consists of a wooden tub, 15 feet in diameter, in which is located the filtering material and collecting system of pipes, while outside of this is a second wooden tub, 16 feet in diameter. The bottom of the latter consists of the filter tub and a circular ring about 6 inches wide outside of the filter tank. The top of the outer tank is approximately 18 inches above that of the inner and the space between the tanks serves as a collector for the water used in washing.

In the bottoms of the filters are placed the strainer systems which comprise manifolds of 1½-inch wrought iron pipes, discharging into larger manifolds, which in turn discharge into the main outlet pipes of the filters. Brass perforated screens or strainers are screwed at six inch intervals into the small wrought iron laterals, which are six inches apart. No gravel is placed over the strainer systems.

The filtering material is 4 feet deep, and consists of silica sand, obtained from Red Wing, Minn., at an original cost of $8.00 per ton, delivered in Elyria. From samples collected in August, 1906, its average effective size was found to be .49 m. m., and its uniformity coefficient 1.4.

The filters are provided with mechanical agitators consisting of steel rakes extending about 2 feet into the sand, and revolving about eight times per minute during washing. The wash water is applied by a compound duplex pump, having a capacity of 28 gallons per revolution. By means of a governor its speed is maintained at 48 revolutions per minute.

The filters are furnished with Weston rate controllers, by which their rate of discharge is automatically governed. Loss of head gages, showing the amount of head lost during filtration, have been installed, but are not used.

Additions to Filters. In 1905, the superintendent built two new concrete filters, each approximately 18 feet by 15½ feet, with an area of 276 square feet. The strainer system of these filters is of an original design and consists of brass perforated strainers screwed 6 inches center to center each way into a false bottom of boiler plate, ¼-inch thick. The total number of these strainers per filter is 900. The boiler plate is fastened to the concrete by bolts around the sides, and as it is not supported in the center, it is found that, during washing, the plates are lifted and also that some of the joints, which are imperfectly fastened by bolts, are opened.

All of the piping of these two filters is of 8-inch wrought iron, although the outlet carrying filtered water to the clear well is throttled to 4 inches in diameter. No rate controllers nor loss of head gages are provided. The filtering material was originally 4 feet deep and was obtained from Cape May, N. J. Its effective size is .51 m. m. and its uniformity coefficient is 1.7. No mechanical nor air agitation is provided, but systems of perforated pipes carrying water at high pressure were installed at about two feet depth in the sand. These pipes are 1¼-inch wrought iron, 18 inches center to center, with ¼-inch perforations every 18 inches. They did not prove efficient and have since been removed from one of the filters.

In 1907, still another concrete filter was built by the superintendent. It is 14.5 feet by 16 feet at the sand line with an area of 232 square feet. The strainer system consists of 1-inch brass pipes 7 inches apart, in which are sawed vertical slots, about ⅛-inch in width, 1-inch apart. These pipes discharge into five 4-inch wrought iron pipes. On the strainer system is placed a layer of unscreened gravel, 14 inches deep, obtained from the shore of the lake. On top of the gravel is the filtering material, which was obtained from selected pockets of sand washed up on the shore of the lake. It is 4 feet deep and has an effective size of .35 m. m. and a uniformity coefficient of 1.7. The total depth of the filter is about 12 feet and about 6 feet of water is carried on the sand. No mechanical agitation is provided, but the sand has washed very satisfactorily with wash water only.

Clear Well. The clear well is located below the floor of the filter house and is 43 feet wide by 64 feet long and has a net area of 2,320 square feet. The total depth of the well is 10 feet and it has a total capacity of 173,500 gallons; the working depth, however, is but 5 feet and the actual available capacity one-half the above figure. At the average rate of pumping, 1,530 gallons per minute, the actual working storage period is 57 minutes.

High Service Pumps. From the clear well the filtered water is pumped directly into the mains by the high service pumps, which comprise one Snow, high duty, cross-compound, crank and fly wheel pump, installed in 1904, with a capacity of 3 million gallons in 24 hours; and one similar pump of 5 million gallons capacity, installed in 1905. There is no storage of filtered water other than that maintained in the clear well. The ordinary pressure carried in the mains at the pumps is 125 pounds per square inch, which is increased in times of fire to from 150 to 160 pounds per square inch.

The force main comprises 40,000 feet of 20-inch cast iron pipe and 4,000 feet of 10-inch cast iron pipe. The reduction in size was made to cut down the cost of installation. On account of the great length and small size of the force main, it is necessary to maintain about 25 pounds more pressure at the pumps than in the distribution system in Elyria. During the latter part of 1907, the 10-inch main has been removed and replaced by a larger pipe.

EXAMINATIONS.

During the special investigation by the State Board of Health, the plant has been visited six times, on May 25th, August (15-17), October (21-29), 1906, February (5-6), June (8-10), October 15th, 1907. Regular examinations were made except on the first and last visits, when the plant was inspected.

OPERATION.

When the Elyria plant is in operation, water flows by gravity from the intake into the forebay, from which it is pumped into the coagulating basins. From the latter it flows by gravity through the filters into the clear well and is forced into the distributing system. As there is no storage for filtered water

Elyria. — Settling Basin from the Southwest Looking Toward the Pump House.

except that contained in the clear well at the plant, it is necessary to operate the plant 24 hours a day. The operation is carried on during three shifts of 8 hours and is in charge of a chief engineer who has three assistants and three firemen. A chemist is employed by the Board of Public Service to make bacterial examinations of the water supply twice a week.

Records of the daily operation of the plant have been furnished the State Board of Health during their special investigation and are shown in Table No. 12.

Average Daily Consumption.

From the daily records it will be seen that the average daily consumption during the investigation has been 2,211,000 gallons. There has been a considerable increase in the consumption and occasionally, as shown during June, 1907, the quantity pumped is considerably in excess of the average. The fact that the average daily consumption is considerably less than the nominal capacity of the filter plant has been an important factor in increasing the ease with which the plant is operated.

General Methods of Operation.

It has been noted that the maximum variation in the depth of water in the clear well during the day is about 2 feet and no difficulty is experienced in maintaining a sufficient storage in the well, even in times of fire. On but one occasion has it been necessary to pump raw water direct; that was before the investigations were started and occurred during the destruction of Hotel Andwur. It is generally the custom to maintain filters 1 to 4, the four original wooden tanks, in constant operation and during such times as their output is not as great as the consumption, to increase the supply by putting one or more of the concrete filters in service.

Methods of Applying Coagulants.

Until the new coagulating basin was provided in 1907, the methods of applying the coagulants have remained unchanged during the investigation. The routine procedure for preparing the lime solution is as follows: Into the slaking tank, containing approximately 800 gallons of cold water, there are placed 80 pounds of unslaked lime. The mixture is stirred thoroughly until well slaked and is then discharged into one of the lime storage tanks which are used alternately and where the strong milk of lime is diluted to a concentrated lime water. No agitation is provided in these solution tanks. The lime water flows by gravity to the ball-cock tank from which it is discharged into the funnel on the suction of the solution pump, and is forced into the raw water main.

The method of preparing the copperas solutions is very similar. The coagulant is dissolved in a small tank and the solution is diluted in the storage tanks from which it flows to the regulating tanks and is pumped into the raw water main.

The rates of application of the solutions are determined by the degree of opening of the globe valves controlling the discharges from the regulating tank. The solution pump is always operated at a rate greater than is required to handle the quantity of solution applied so that the rate of application is independent of the speed of the solution pump.

During the examinations numerous samples have been taken to determine the variations in the strengths of the coagulant solutions and also the percentage of the chemicals actually available.

Quantity of Coagulant Applied.

The method employed to coagulate the water is to introduce such a quantity of copperas as is deemed necessary and then to so adjust the quantity of lime that there results a slight red color in the filtered water when tested with phenolphthalein. The average quantity of copperas used during the investigation, as shown on the daily records, is .75 grain per gallon and has required .33 grain of lime for its precipitation. The maximum quantity of copperas used, as shown in the daily records, is 1.6 grain per gallon on April 18, 1907; during which time 0.77 grain of lime per gallon was also used. The turbidity of the lake was then 750 parts per million.

The above proportion would show that .44 grain of lime per gallon was necessary to precipitate one grain of copperas per gallon. The proportion between the coagulants has been maintained nearly constant at Elyria and no difficulty has been encountered with "after deposits" of lime in the filters; there has also resulted less iron in the filtered than in the raw water.

Coagulating Basins.

The operation of the coagulating tanks has required little attention. The automatic alarm showing the height of water contained in the tanks has permitted a very satisfactory regulation of the low service pumps. There is very little deposition of suspended matter in the tanks and it is seldom necessary to clean them.

Filters.

Rate of Filtration. The four original filters are provided with Weston rate controllers, and during the investigation it has been found that these controllers have been very efficient and the average rate of filtration of these filters has been 135 million gallons per acre per day. As there is a considerable hourly variation in the consumption of water, it is necessary on account of the lack of a distributing reservoir to vary the output from the filters corresponding to the changes in the consumption. The maximum consumption prevails for a period of several hours, during which time it is necessary to operate the four original filters and at least two of the concrete units. At other times, particularly during the night, the consumption is greatly decreased and frequently two filters will furnish the necessary quantity of water. The four original filters are always operated at a constant rate, while the concrete units are generally maintained at a rate of about 70 or 80 million gallons per acre per day.

Washing. As the filters are washed by a direct acting pump, the speed of which is accurately regulated by a governor, the rate of application of the wash water is practically the same for all the filters. From numerous measurements during the investigation, the average rate of washing was found to be 1080 gallons per minute.

It is generally necessary to wash each of the four original filters three times a day. The wash water is applied at 1080 gallons per minute for 15 minutes, corresponding to 16,200 gallons per wash, or 12.2 vertical feet. At 12 washes per day, the total quantity of water used to wash these filters is 194,000 gallons, which is 11 per cent. of the quantity of water filtered by them. This quantity is unusually high and is due to the short period allowed for the coagulation of the applied water and to the use of small quantities of coagulant.

The concrete filters have been operated during but 5 hours per day at a rate of 75 million gallons per acre per day, so that the quantity of water filtered by them is 158,000 gallons. The average number of washes of these filters per day is 0.45, and they have been washed at the same rate, 1080 gallons per minute for

10 minutes, which corresponds to the use of 10,000 gallons of wash water per day, or 6.4 per cent. of the quantity filtered.

From the daily records it will be seen that the average quantity of wash water used per day is 202,000 gallons, which corresponds to 8.4 per cent. of the total quantity of water filtered. This per cent. is high and is due to the use of small quantities of coagulant and to the poor preparation of the water for filtration.

CHARACTER OF RAW WATER.

During each of the examinations of the Elyria plant, samples of the raw or untreated water have been obtained from a tap at the raw water pump. There have been less fluctuations in the character of the raw water at Elyria than at any other plant in the state, a fact which is due to the absence of local features that would tend to influence the quality of the lake water. Chemically the raw water is of nearly constant hardness and contains but very small quantities of dissolved color. Considerable variation is noted in the turbidity of the water at the intake and occasionally it is very dirty, due to the action of heavy seas which tend to stir up the deposited silt from the bottom of the lake. At such times, although the water contains considerable suspended matter, experience has shown that it is more easily coagulated and purified than when clear. When there are strong northeast winds, however, it appears that the suspended matter is of a somewhat different character than is caused by the northwest winds, and that at such times the raw water contains a fine blue clay which is very difficult to subside and which causes a rapid clogging of the filters.

On the examination of October (21-29), 1906, owing to repairs of the raw water pumps, it was necessary to pump unpurified lake water from 9:00 a. m. October 24th until 9:00 a. m. October 27th. Unfortunately, there was a very heavy northwest gale on the night of October 25th and there resulted a very rapid and considerable increase in the turbidity and suspended matter in the raw water. It is of interest to note, however, that coli were present in but three samples, and then in 100 c. c. portions.

During the examination of February (5-6), the lake was covered with ice, and the water was unusually clear.

During the examination of June (8-10), 1907, quantitative determinations of the coli in the raw water were determined using different dilutions of bile media. The results obtained are of considerable interest. On June 8th, there was a strong northeast wind, causing an increase in the turbidity of the lake, and the analyses indicate the presence of one coli per c. c. On June 10th, the wind had changed to the southeast, and although coli were present in 1.0 c. c. in the first sample none were found in 2 c. c. at 10 a. m. The evidence indicates that during northeast winds there is a slight pollution of the water at the Elyria intake, due to lake currents carrying the polluted waters from Black River.

In general it may be said that the evidence indicates that under usual conditions the water at the Elyria intake contains but little pollution and represents normal lake water. Except during periods of northeast wind, when the purity of the water is effected by pollution from Black River, the satisfactory operation of the filter plant requires merely the removal of objectionable suspended matters.

EFFICIENCIES.

GUARANTEE.

The contract covering the construction of the original filter plant contains the guarantee that the effluent shall be clear, odorless, free from turbidity and of matter visible to the naked eye. That the bacterial removal shall be at least

98 per cent. when the raw water contains 3,000 or more per c. c., and that the effluent shall contain not more than 100 per c. c. when the raw water contains less than 3,000, per c. c.

Means for Applying Coagulant.

During the examinations of February (5-6) and June (8-10), 1907, samples of the coagulant solutions were taken from the discharge of the coagulating tanks, and were analyzed at the plant for the available lime as CaO and copperas. The results of the titrations, together with the length of the examinations and the theoretical strength of the solutions are shown in Table No. 9. The theoretical strength of the lime is figured assuming that it contains 100 per cent. CaO. The table shows that the average quantity of lime available as CaO has been 66 per cent.

It will also be seen that there is a considerable variation between the maximum and minimum strengths of the solutions. The maximum strengths have occurred at such times as a new solution tank was started in service, while the minimum strengths occur at the end of the run-off of the tank.

During the examination of February (5-6), 1907, it was necessary to keep water flowing through the supply pipe to the copperas solution tanks, in order to prevent freezing. On this account there resulted a considerable decrease in the strengths of the copperas solutions toward the end of the runs, and it was impossible to determine the theoretical amount of copperas available. The considerable variations in the strength of the lime water are due in part to deposition in the solution tanks, which contain no agitators; also to incomplete washing out of the lime slaking box and to variations in the percentage purity of the lime used.

TABLE NO. 9.

Strength of Solutions.

(Grains per Gallon.)

Lime.						Copperas.					
Date.	No. of Samples.	Theor.	Max.	Min.	Aver.	Date.	No. of Samples.	Theor.	Max.	Min.	Aver.
1907.											
2/5–6	31	58	67	31	41.1	2/5–6	31	200	294	48	178
6/8–10	30	95	91	43	58.8	6/8–10	30	278	315	183	237

Coagulating Basins.

During the examinations of February 5th and June 8th, 1907, samples of the coagulated water were obtained from the top of one of the filters. The evidence indicates a considerable variation in the bacterial removal accomplished in the coagulating tanks as the percentage removal has varied from 50 to 0 per cent. The turbidity analyses of June (8-10) show that there was more suspended matter contained in the water applied to the filters than in the raw water.

In general it may be said that the coagulating basins have provided a storage period of practically one hour, which is perhaps sufficient for the completion of the chemical reaction of the coagulants, but that as a rule there is but little deposition of bacteria or suspended matter in the tanks. This fact is largely responsible for the large per cent. of wash water required to clean the filters. Although no difficulty is encountered in always obtaining a sufficient quantity of filtered water at the plant, this is due to the unusually large proportion between the filtering capacity provided and the average daily consumption.

Filters.

Considerable variation has been noted in the character of the filtered water. On the first two examinations the average number of bacteria per c. c. in the filtered water was less than 100, but this was not true in either of the examinations in 1907. The comparatively poor results have been due in part to the poor condition of the filtering material caused by imperfect washing of the filters.

Considerable trouble has been experienced in washing all of the filters apparently caused by fine blue clay in the raw water, particularly during northeast winds. This clay has not been removed by the coagulating tanks. During the first examinations of October (21-29), 1906, and February (5-6), 1907, it was found that although mechanical agitation is provided, the sand in the four wooden filters was not satisfactorily washed and contained many hard spots.

The means provided for washing the first concrete filters have not proved efficient. It was intended to apply the wash water to these filters at considerably greater rates than to the others, but the metal false bottoms are not sufficiently supported and when the wash water is applied at too great a rate, there results both a lifting of the false bottoms and a tendency to open the joints. During each of the examinations the sand in these filters has contained numerous hard spots, which have eventually been removed by shoveling out the dirty sand and also by working them over with a bar.

In order to assist the washing of the filters, a small air pump was provided in the fall of 1907, and since its use no difficulty has been experienced in maintaining the sand in all the filters in very good condition.

The low bacterial reductions by the filters as indicated in the analyses have been largely due to the use of small quantities of the coagulants. At the first examination advice was requested relative to the amount of coagulant and degree of purification necessary, so that the use of the small quantities of coagulants that has followed this examination was in part due to recommendations made at that time. In judging the efficiency of the Elyria filter plant, it should be considered that there is little evidence of local pollution at the intake, and that as the raw water is essentially representative of that in the lake, its purification requires merely the removal of the suspended matters to produce a potable water supply. In the several examinations there have been but two samples of filtered water that have been found to contain coli and then only in 100 c. c. portions. The water furnished has been clear, practically colorless, and has contained no evidence of pollution (indicated by the absence of coli), so that while the actual percentage of bacterial removal by the filters is perhaps low, the effluent has always been potable.

SUMMARY OF RESULTS OF SPECIAL INVESTIGATION.

The evidence obtained during the investigation by the State Board of Health has indicated that the Elyria water supply has been clear, colorless, and of excellent quality for domestic use. While the total number of bacteria con-

tained has perhaps been greater than is sometimes considered advisable, yet the absence of pollution would show that the number of bacteria contained has little significance. Considerable expense was incurred in locating the Elyria plant at a point well removed from local pollution, and while its position at a point about nine miles from the center of Elyria necessitates a somewhat greater cost of pumping, the net cost of operation is low partly from the fact that less coagulants are required to produce a satisfactory water supply than if a less desirable location had been obtained.

Unfortunately, no examination has been made since the installation of the new coagulating basin, but it is stated that the use of this basin has resulted in a considerable reduction in the amount of coagulant and wash water required.

No trouble has been experienced at Elyria from the use of copperas and lime as coagulants, a fact which probably results from their application in certain definite proportions. As no excess quantity of lime is applied, there has resulted no "after deposits" in the filters and the evidence indicates that the present method of adjustment of the coagulants, resulting in the slight phenol alkalinity of the filtered water, is calculated to produce the best results.

COST OF INSTALLATION AND MAINTENANCE.

In Table No. 10 is shown the cost of the new plant as constructed in 1903, and also the cost of the additional filters subsequently added and of the new settling basin. The cost of the settling basin includes also the furnishing and laying of the connections from the pumps to the filters. There is included a cost for pipes and laying of approximately $162,000, which covers the cost of installation of the force main from the pumping plant to Elyria and the extensions to the distributing system. This first cost for piping is unusually large, but the careful selection of the site for the pumping plant has made it possible to operate the plant very economically and also to obtain very satisfactory results.

TABLE NO. 10.

Cost of Installation.

Intake	$15,841
Building and lands	27,829
Pumps and boilers	28,761
Filter plant — original installation. (Includes one raw water pump, 4 filters and 2 coagulating tanks.)	18,650
Filter plant — additional filters	5,000
New settling basin (Includes connections also.)	9,800
Pipes and laying (Includes force main and extensions to distributing system.)	161,974
Total cost	$267,855

In Table No. 11 is shown the cost of maintaining the pumping station and filters during the year 1907. The total cost of maintaining the plant was but $13. per million gallons, not including interest, a figure which is unusually low and is due largely to careful and efficient management of the plant. It is of interest to note the very low cost of coagulant, $650. It has been possible to operate the plant with a very economical use of coagulant because, as above mentioned, there is no local pollution and a high degree of purification is not required.

TABLE NO. 11.

Cost of Operation — 1907.

Labor		$6,516
Chief engineer	$1,080	
3 assistants	2,700	
3 firemen	2,448	
Bacteriologist	288	
Fuel, 1,500 tons at $1.80 per ton		2,700
Coagulants		656
Copperas, 0.48 per lb	$438 00	
Lime, 0.473 per lb	218 00	
Incidentals		619
Total cost of operation		$10,491
Total consumption, 1907 (Est.)		807,000,000
Cost per million gallons		$13 00
Includes labor per million gallons	$8 07	
Fuel per million gallons	3 34	
Coagulants per million gallon	81	
Incidentals per million gallons	78	

TABLE NO. 12.

Elyria — Record of Operation.

Month.	Average Daily Consumption.	Gallons Filtered.	Wash Water.		Coagulants Used.				Turbidity of Raw Water.
			Gallons.	Per Cent.	Pounds.		Gr. p. Gal.		
					Cop.	Lime.	Cop.	Lime.	
1906.									
October ...	2,069,000	2,276,000	207,000	9.0	155	82	0.5	0.27	112
November .	1,987,000	2,172,000	195,000	8.9	156	84	0.5	0.29	119
December .	1,992,000	2,191,000	199,000	9.0	173	91	0.6	0.30	155
1907.									
January ...	2,170,000	2,371,000	201,000	8.4	175	87	0.5	0.28	182
February ..	2,364,000	2,568,000	204,000	7.9	150	80	0.4	0.20	75
March	2,316,000	2,521,000	205,000	8.1	299	120	0.9	0.30	149
April	2,164,000	2,369,000	205,000	8.6	426	197	1.3	0.60	286
May	2,059,000	2,261,000	202,000	8.9	300	125	1.0	0.40	121
June	2,524,000	2,726,000	202,000	7.4	300	125	0.8	0.30	228
July	2,356,000	2,558,000	202,000	7.8	300	125	0.9	0.37	.....
August	2,324,000	2,526,000	202,000	7.9	300	125	0.9	0.37	.....
Aver....	2,211,000	2,412,000	202,000	8.4	249	113	0.75	0.33	160

TABLE NO. 13.

Elyria — Results of Analyses During Examinations.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Phen. Alk.
	1906	P. M.								
400	8-15	3:00	Raw water	780	.....	.....	.....	50	.....	.....
408	8-15	9:00	Raw water[1]	2,300	.....	.....	.....	40	91	3.0
			Average	1,540	.....	.....	.....	45	91	3.0
401	8-15	3:00	Filtered water[2]	15	.....	.....	.....	8	93	3.
409	8-15	9:00	Filtered water	68	.....	.....	.....	<5	92	3.5
			Average	42	.....	.....	.....	4	93	3.2
402	8-15	3:30	Effluent No. 1	9	.....	.....	.....	.....	.....	.....
403	8-15	3:30	Effluent No. 2	26	.....	.....	.....	.....	.....	.....
404	8-15	3:30	Effluent No. 3	4	.....	.....	.....	.....	.....	.....
405	8-15	3:30	Effluent No. 4	19	.....	.....	.....	.....	.....	.....
406	8-15	3:30	Effluent No. 5	9	.....	.....	.....	.....	.....	.....
407	8-15	3:30	Effluent No. 6	9	.....	.....	.....	.....	.....	.....
			Average	13	.....	.....	.....	.....	.....	.....
		A. M.								
410	8-16	8:00	Raw water	550	.....	.....	.....	40	90	1.0
412	8-16	9:30	Raw water	660	0	0	.....	38	90	1.0
		P. M.								
419	8-16	4:00	Raw water	155	0	0	.....	40	89	3.0
421	8-16	10:00	Raw water	255	0	0	.....	35	89	2.0
			Average	405	.....	.....	.....	38	90	1.7
		A. M.								
411	8-16	8:00	Filtered water	72	.....	.....	.....	<5	93	3.5
413	8-16	9:30	Filtered water	32	0	0	.....	<5	92	5.0
		P. M.								
420	8-16	4:00	Filtered water	16	0	0	0	<5	91	2.0
422	8-16	10:00	Filtered water	44	0	0	.....	<5	87	1.0
			Average	41	.....	.....	.....	<5	91	2.2
		A. M.								
414	8-16	10:50	Effluent filter No. 5	34	.....	.....	.....	.....	.....	.....
415	8-16	10:50	Effluent filter No. 6	129	.....	.....	.....	.....	.....	.....
416	8-16	10:50	Effluent filter No. 4	15	.....	.....	.....	.....	.....	.....
417	8-16	10:50	Effluent filter No. 3	48	.....	.....	.....	.....	.....	.....
418	8-16	10:50	Effluent filter No. 2	16	.....	.....	.....	.....	.....	.....
			Average	49	.....	.....	.....	.....	.....	.....
	1906	A. M.								
423	8-17	4:00	Raw water	85	0	0	.....	30	90	2.0
425	8-17	11:00	Raw water	360	0	0	.....	40	91	0.5
		P. M.								
433	8-17	4:00	Raw water	250	0	0	.....	35	90	2.0
			Average	232	0	0	.....	35	90	1.5
		A. M.								
424	8-17	4:00	Filtered water	73	0	0	.....	<5	87	0
426	8-17	11:00	Filtered water	26	0	0	.....	<5	88	0.5
		P. M.								
434	8-17	4:00	Filtered water	22	0	0	.....	<5	88	1.0
			Average	40	0	0	.....	<5	88	0.7

[1]Stood 13 hours before plating.
[2]From tap in bath room.
Iron (Fe), Samp. No. 401, 0.8; Samp. No. 409, 0.1; Samp. No. 411, 0.8; Samp. 420, 0.2; Samp. No. 424, 0.2.
Aug. (15-17) 1906, used 0.7 gr. of copperas p. gallon and 0.4 gr. of lime p. gallon.

TABLE NO. 13 — Continued.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Phen. Alk.
		P. M.								
427	8-17	2:15	Effluent No. 1	8	.....	.....	.....	.....	.....	.....
428	8-17	2:15	Effluent No. 2	9	.....	.....	.....	.....	.....	.....
429	8-17	2:15	Effluent No. 3	3	.....	.....	.....	.....	.....	.....
430	8-17	2:15	Effluent No. 4	12	.....	.....	.....	.....	.....	.....
431	8-17	2:15	Effluent No. 5	5	.....	.....	.....	.....	.....	.....
432	8-17	2:15	Effluent No. 6	27	.....	.....	.....	.....	.....	.....
			Average	11	.....	.....	.....	.....	.....	.....
		A. M.								
700	10-21	8:00	Tap at Hotel Andwur	380	.....	.....	0	<5	88	0.5
701	10-22	6:00	Tap at Hotel Andwur	230	.....	.....	.....	<5	87	0
		P. M.								
702	10-23	10:00	Tap in house, East Avenue	180	.....	0	.....	.....	.....	.....
703	10-24	2:00	Tap in force main at plant[1]	1,200	.....	.....	.....	.....	.....	.....
704	10-25	1:30	Tap in force main at plant	2,250	0	+	.....	140	98	1.5
705	10-25	7:30	Tap at Hotel Andwur	1,650	0	0	.....	.....	.....	.....
		A. M.								
706	10-26	7:30	Fountain in square	1,600	0	+	.....	.....	.....	.....
707	10-26	8:00	Tap at Hotel Andwur	3,100	0	0	.....	80	98	1.5
708	10-26	3:00	Tap at pump house[2]	1,750	0	+	.....	60	99	2.0
		A. M.								
714	10-28	9:30	Raw water[3]	1,300	0	0	.....	240	96	0.5
		P. M.								
717	10-28	1:30	Raw water	1,000	.....	.....	.....	470	97	.....
719	10-28	4:00	Raw water	1,000	.....	.....	.....	175	.....	.....
721	10-28	10:00	Raw water	800	.....	.....	.....	150	94	0.5
			Average	1,025	.....	.....	.....	259	96	0.5
	1906	A. M.								
713	10-28	9:00	Water on No. 8	600	.....	.....	.....	120	95	.5
		P. M.								
718	10-28	2:00	Water on No. 3	375	.....	.....	.....	115	90	.0
			Average	488	.....	.....	.....	118	93	.5
		A. M.								
709	10-28	8:00	Filtered water	250	0	0	.....	5±	95	.0
715	10-28	10:30	Filtered water	170	0	0	.....	5±	95	.5
		P. M.								
716	10-28	1:30	Filtered water	180	.....	.....	.....	5±	96	.5
720	10-28	4:30	Filtered water	190	.....	.....	.....	5±	94	.5
722	10-28	10:00	Filtered water	220	.....	.....	.....	.....	91	.5
			Average	202	0	0	.....	5±	94	.5
		A. M.								
710	10-28	8:30	Effluent No. 3	180	.....	.....	.....	.....	.....	.....
711	10-28	8:30	Effluent No. 4	90	.....	.....	.....	.....	.....	.....
712	10-28	8:45	Effluent No. 1	80	.....	.....	.....	.....	.....	.....
			Average	117	.....	.....	.....	.....	.....	.....
		A. M.								
723	10-29	4:00	Raw water	700	.....	.....	.....	145	99	.5
725	10-29	9:00	Raw water	1,000	0	0	.....	150	100	.5
		P. M.								
733	10-29	2:00	Raw water	500	0	+	.....	110	92	.5
			Average	733	.....	.....	.....	135	97	.5

[1]Started to pump raw water at 9 A. M., 10-24.
[2]Started to pump filtered water at 9 A. M., 10-27; heavy N. W. gale blowing since Wed., 10-26.
[3]Started coagulant at 9 A.M., 10-28.
[4]No lime and iron used.
Oct. 28-9, 1906, used 0.76 gr. of copperas p. gallon and 0.37 gr. of lime p. gallon.

TABLE NO. 18 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Phen. Alk.
783	10-29	A. M. 10:00	Settled water on No. 3.....	600	.....	.....	.....	.....	95	4.0
785	10-29	P. M. 2:00	Settled water on No. 3.....	450	.....	.....	.....	.....	104	9.0
			Average	525	.....	.....	.....	.....	100	6.5
734	10-29	A. M. 4:00	Filtered water	95	.....	.....	.....	<5	94	.5
736	10-29	9:30	Filtered water	75	0	0	.....	<5	93	4.0
784	10-29	P. M. 2:00	Filtered water	70	0	0	.....	<5	94	4.0
			Average	80	0	0	.....	<5	94	4.0
727	10-29	A. M. 10:00	Effluent No. 2.....	35	.....	.....	.....	.....	.....	.....
728	10-29	10:00	Effluent No. 3.....	75	.....	.....	.....	.....	.....	.....
729	10-29	10:00	Effluent No. 4.....	180	.....	.....	.....	.....	.....	.....
730	10-29	10:00	Effluent No. 5.....	90	.....	.....	.....	.....	.....	.....
731	10-29	10:00	Effluent No. 6.....	46	.....	.....	.....	.....	.....	.....
			Average	85	.....	.....	.....	.....	.....	.....
971	1907 2-5	A. M. 7:00	Raw water[1]	6,300	.....	.....	5	30	80	.....
981	2-5	11:00	Raw water	2,800	0	+	.....	30	80	.....
991	2-5	P. M. 3:00	Raw water	2,000	0	+	.....	30±	82	.....
995	2-5	9:00	Raw water	Lost	0	+	.....	30±	82	.....
			Average	3,700	.....	.....	.....	30±	81	.....
972	2-5	A. M. 7:30	Set. water top filter No. 1...	3,500	.....	.....	.....	.....	81	.....
982	2-5	11:00	Set. water top filter No. 1...	350	0	.....	.....	.....	87	.....
992	2-5	P. M. 3:00	Set. water top filter No. 1...	950	.....	.....	.....	.....	89	9.0
996	2-5	9:00	Set. water top filter No. 1..	Lost	.....	.....	.....	.....	92	8.0
			Average	1,770	.....	.....	.....	.....	87	8.5
973	2-5	A. M. 7:30	Tap in bath room, pump house	350	0	0	5	<5	85	0
990	2-5	P. M. 1:30	Tap in bath room, pump house	12	.....	.....	5	<5	84	0.5
994	2-5	5:00	Tap in bath room, pump house	Lost	.....	.....	5	<5	88	4.0
997	2-5	9:00	Tap in bath room, pump house	Lost	0	0	5	<5	88	0
			Average	181	.....	.....	5	<5	86	2.2
974	2-5	A. M. 9:30	Clear well	275	0	0	5	<5	87	0.5
983	2-5	11:00	Clear well	325	0	+	5	<5	84	0
998	2-5	P. M. 3:00	Clear well	80	0	0	5	<5	88	5.0
			Average	225	.....	.....	5	<5	86	2.0

CO_2, Samp. No. 971, 1.0; No. 981, 1.0; No. 991, 1.5; No. 995, 1.0; No. 972, 1.0; No. 982, 0.5; No. 998, 1.0; No. 1001, 0.5; No. 1010, 1.0.

[1]Lake covered with ice.

TABLE NO. 13 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C.C.	Colon in 100 C.C.	Parts Per Million. Col.	Turb.	Alk.	Phen. Alk.
		A. M.								
975	2-5	9:30	Effluent filter No. 1	170	.....	.....	.....	.....	.....	.....
976	2-5	9:30	Effluent filter No. 2	275	.....	.....	.....	.....	.....	.....
977	2-5	9:30	Effluent filter No. 3	230	.....	.....	.....	.....	.....	.....
978	2-5	9:30	Effluent filter No. 4	180	.....	.....	.....	.....	.....	.....
979	2-5	9:30	Effluent filter No. 5[2]	475	.....	.....	.....	.....	.....	.....
980	2-5	9:30	Effluent filter No. 6	500	.....	.....	.....	.....	.....	.....
		P. M.								
984	2-5	1:30	Effluent filter No. 1	150	.....	.....	3	<5	85	0.5
985	2-5	1:30	Effluent filter No. 2[3]	160	.....	.....	.....	.....	.....	.....
986	2-5	1:30	Effluent filter No. 3[3]	90	.....	.....	.....	.....	.....	.....
987	2-5	1:30	Effluent filter No. 4[3]	230	.....	.....	.....	.....	.....	.....
988	2-5	1:30	Effluent filter No. 5[3]	170	.....	.....	.....	.....	.....	.....
989	2-5	1:30	Effluent filter No. 6	16	.....	.....	.....	.....	.....	.....
			Average	220	.....	.....	.....	.....	.....	.....
	1907	A. M.								
998	2-6	2:00	Raw water	Lost	0	±	3	30±	88	.....
1001	2-6	7:00	Raw water	Lost	0	±	.....	30±	88	.....
		M.								
1010	2-6	12:00	Raw water	Lost	.....	.....	.....	30±	88	.....
			Average	.....	.....	.....	3	30±	88	.....
		A. M.								
999	2-6	2:00	Settled water	Lost	.....	.....	.....	.....	87	2.0
1002	2-6	7:00	Settled water	Lost	.....	.....	.....	.....	87	9.0
		M.								
1011	2-6	12:00	Settled water[4]	Lost	.....	.....	.....	.....	98	12.0
			Average	.....	.....	.....	.....	.....	89	8.0
		A. M.								
1000	2-6	2:00	Tap in bath room	Lost	0	0	3	<5	87	4.0
1003	2-6	7:00	Tap in bath room	Lost	0	0	3	<5	86	6.5
			Average	.....	0	0	3	<5	87	5.0
		M.								
1012	2-6	12:00	Effluent filter No. 1	Lost	0	0	5	<5	98	11
		A. M.								
1007	2-6	10:00	Effluent filter No. 4	300	.....	.....	.....	.....	.....	.....
1004	2-6	10:00	Effluent filter No. 1	Lost	.....	.....	.....	<5	88	10
			Average	300	.....	.....	5	<5	91	11

[2]Just started.
[3]Just after washing.
[4]No copperas applied.
Feb. 5-6, 1907, used 0.8 gr. of copperas p. gallon and 0.6 gr. of lime p. gallon.

TABLE NO. 13 — Continued.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in				Parts Per Million.			
	Date.	Hour.			.5 c.c.	1 c.c.	2 c.c.	100 c.c.	Col.	Turb.	Alk.	Phen. Alk.
	1907	A. M.										
1402	6-8	7:00	Raw water[1]	1,400	+	+	+	....	10	70	81	0
1406	6-8	9:00	Raw water	3,900	+	+	+	....	15	70	81	0
1410	6-8	11:00	Raw water	1,000	+	+	+	....	15	90	82	0
		P. M.										
1414	6-8	1:00	Raw water	2,100	0	+	+	....	15	90	82	0
1418	6-8	3:00	Raw water	1,200	0	+	+	....	15	100	82	0
			Average	1,920	....	....	....	....	14	85	82	0
		A. M.										
1408	6-8	7:00	Set. water top filter No. 1	1,000	....	....	....	....	.....	120	84	11
1407	6-8	9:00	Set. water top filter No. 1	3,500	....	....	....	....	.....	100	86	10
1411	6-8	11:00	Set. water top filter No. 1	1,800	....	....	....	....	.....	100	88	12
		P. M.										
1415	6-8	1:00	Set. water top filter No. 1	2,700	....	....	....	....	.....	100	88	10
1419	6-8	3:00	Set. water top filter No. 1	1,000	....	....	....	....	.....	110	92	12
			Average	2,000	....	....	....	....	.....	105	88	11
		A. M.										
1404	6-8	7:00	Filtered water	375	....	....	....	0	14	<5	68	6
1405	6-8	8:00	Filtered water	300	....	....	....	0	.....	.....	.....	.....
1408	6-8	9:00	Filtered water	475	....	....	....	0	10	<5	70	6
1409	6-8	10:00	Filtered water	450	....	....	....	0	10	<5	76	6
1412	6-8	11:00	Filtered water	400	....	....	....	+	10	<5	77	4
		M.										
1413	6-8	12:00	Filtered water	300	....	....	....	0	15	<5	77	3
		P. M.										
1416	6-8	1:00	Filtered water	275	....	....	....	0	10	<5	77	6
1417	6-8	2:00	Filtered water	100	....	....	....	0	10	<5	76	6
1420	6-8	3:00	Filtered water	225	....	....	....	0	14	<5	80	4
1421	6-8	4:00	Filtered water	250	....	....	....	0	15	<5	81	6
			Average	315	....	....	....	0	12	<5	75	5
		A. M.										
1422	6-10	8:00	Raw water[2]	.....	0	+	+	....	6	35	83	0
1425	6-10	10:00	Raw water	.....	0	0	0	....	6	35	82	0
		M.										
1428	6-10	12:00	Raw water	.....	0	0	+	....	6	40	83	0
		P. M.										
1431	6-10	2:00	Raw water	.....	....	....	....	....	6	70	84	0
			Average	.....	....	....	....	....	6	45	83	0
1423	6-10	8:00	Set. water top filter No. 1	.....	....	....	....	....	.....	.....	90	+11
1426	6-10	10:00	Set. water top filter No. 1	675	....	....	....	....	.....	60	73	— 6
		M.										
1429	6-10	12:00	Set. water top filter No. 1	.....	....	....	....	....	.....	.....	92	+12
		P. M.										
1432	6-10	2:00	Set. water top filter No. 1	.....	....	....	....	....	.....	50	94	+13
			Average	.....	....	....	....	....	.....	55	87	+ 7.5

[1]Northeast wind blowing.
[2]Southeast wind blowing.
June (8-10) 1907, used 0.92 grain of copperas per gallon and 0.50 grain of lime per gallon.

TABLE NO. 13 — Concluded.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in				Parts Per Million.			
	Date.	Hour.			.5 c.c.	1 c.c.	2 c.c.	100 c.c.	Col.	Turb.	Alk.	Phen. Alk.
		A. M.										
1424	6-10	8:00	Filtered water	.....	....	....	....	....	4	<5	76	5
1427	6-10	10:00	Filtered water	.....	....	....	....	0	6	<5	81	5
		M.										
1430	6-10	12:00	Filtered water	.....	....	....	....	0	4	<5	82	5
		P. M.										
1433	6-10	2:00	Filtered water	.....	....	....	....	0	6	<5	80	4
			Average	.....	....	....	....	....	5	<5	80	5

FOSTORIA.

The city of Fostoria is in the north central part of Ohio in Seneca County on Portage Creek. In 1906 its population was estimated at 10,000. As a railroad center, it contains a number of small industries, among which may be mentioned the manufacture of steel nails, cement and lime.

HISTORICAL.

The waterworks for Fostoria were first installed in 1891 and the source of the supply was the east branch of Portage River commonly called Portage Creek. The intake was located south of the city above any local pollution.

Above the waterworks the creek has a watershed of approximately 30 square miles,, on which there is a population of from 600 to 700 people, living mainly in small settlements, the largest of which is West Independence, with a population of about 150. Although there are no municipal systems of water supply or sewerage at these places, there is always a liability of occasional pollution of a dangerous nature entering the stream, such that the water is not considered satisfactory as a supply for domestic purposes without purification.

On account of its small drainage area, the stream frequently has little or no flow during the dry seasons, so that when the waterworks for Fostoria were installed in 1891, it was necessary to provide impounding reservoirs for use during such times as there was not sufficient flow in the creek.

As built in 1891, the waterworks of Fostoria comprised two impounding reservoirs on Portage Creek, a sand "filter," a large pump well, a storage well, a pumping plant, a stand-pipe for storage purposes, and a distributing system. All of these features have been maintained until the present time with the exception of the filter, which was replaced by a slow sand filter plant of more modern design in 1906, at which time also the storage well was rebuilt.

The old filter comprised a circular bed of sand and gravel, contained in a shallow uncovered pit or well and had an area of 6,300 square feet. The filtering material consisted of 12 inches of sand, supported on 18 inches of gravel. The effluent was collected by wooden underdrains and conveyed by a wooden conduit to the pump well. An open basin of 500,000 gallons capacity was provided for the storage of the surplus filtered water.

In practice it was found that the filter acted merely as a strainer for the removal of the coarser suspended particles in the water and from a series of

analyses made by the chemist of the State Board of Health, it was found that there was practically no bacterial purification accomplished by the filter.

On account of the poor efficiency obtained, and also from the fact that there was not a sufficient storage in the reservoir to meet the demands during the dry season, in 1904 permission was requested of the State Board of Health to install a new intake in Portage Creek, which it was intended to use as a source of supply when the creek water was clearer than that in the reservoir. On December 12th, 1904, the Board approved the new intake provided "that filters of either the mechanical or slow sand type of a design satisfactory to the State Board of Health, be constructed before the water from said proposed intake is delivered to consumers."

On June 14th, 1905, plans for a slow sand filtration plant to be used for filtering both the present and the proposed additional water supply for the city of Fostoria were submitted to the State Board of Health, and approved under the following conditions:

First — That the filters and also the clear water basin be covered whenever, in the opinion of the State Board of Health, it is shown that proper results at Fostoria cannot be obtained with the uncovered filters.

Second — That the bottom six inches of filtering material be composed of clean gravel or broken stone, all of which will pass through a screen having 2.5 inch mesh and which will be retained upon a screen having a 1-inch mesh; that the next three inches above shall be composed of clean gravel or broken stone, all of which will pass through a screen having a 1-inch mesh but be retained upon a screen having a clear mesh of ⅝ of an inch; that the next three inches be composed of fine broken stone or gravel, all of which will pass a screen having a clear mesh of ⅝ of an inch but which must be coarser than the sand used for the upper portion of the filter, and be entirely free from clay, dust or other fine material; that the upper three feet of the filtering material be composed of sand of the same size and character as the sample of "local bank" sand, marked No. 2, submitted to the State Board of Health on June 12, 1905, for inspection, by the consulting engineer, after all stones greater than ⅝ of an inch in diameter have been removed from said sample; or be composed of sand, representative samples of which will fulfill the following requirements: Not more than 10 per cent. shall pass the sieve having a clear mesh of .27 of a millimeter, and at least 10 per cent. shall pass a sieve having a clear mesh of .40 of a millimeter; at least 70 per cent. shall pass through a clear mesh of .83 of a millimeter, and at least 90 per cent. shall pass through a clear mesh of 2.5 millimeters (about 3-32 of an inch); sand shall be practically free from clay, dust or organic impurities, and shall be washed before being placed in the filter, if deemed necessary by the State Board of Health.

Third — That if the sand represented by the above mentioned sample No. 2 of local bank sand is used, such sand shall either be washed before being placed in the filters or else the water which first passes through the filter shall be wasted until found, upon examination by the State Board of Health, to be free from clay or organic matter taken up from the filtering material.

Fourth — That the old gravel filter near the pumping station be abandoned and that the entire public water supply of Fostoria be passed through the new proposed filters.

Fifth — That the water direct from the creek through the new intake be used only when such water is clear.

Sixth — That any change in the management or operation of the filters be made when requested by the State Board of Health.

The filter plant was constructed by a local engineer, and started in operation in December, 1906.

DESCRIPTION OF PRESENT WATERWORKS.*

During the special investigation by the State Board of Health, the waterworks of the city of Fostoria has comprised two impounding reservoirs, a small dam and intake in Portage Creek, two slow sand filters, a clear well, a pumping station, and a stand-pipe for storage purposes. Both the reservoir supply and that obtained directly from the river are filtered, and it is intended to use the direct intake provided in 1906 only at such times as the water in the creek is clearer than that in the reservoir.

Impounding Reservoirs.

The impounding reservoirs are near Portage Creek, one-half mile south of the city and above local pollution. Water is taken from the creek into a diverting canal through three gates 6 feet high and 7 feet wide, which can be raised or lowered at will, so that when the creek water is objectionable it can be excluded from the canal. These gates are left open except during flood times, but are closed until the first flood after heavy rains has washed out the creek. The canal for carrying water to the reservoir is 21 feet wide, 2 feet deep and 3,400 feet long.

The upper reservoir has an area of 12 acres and a capacity of 25,000,000 gallons, with an average depth of about 6 feet. Its banks are not paved, nor was the site stripped of vegetation. By a conduit 3 feet in diameter and 400 feet long, the water is conveyed from the upper to the lower reservoir, which has an area of 18 acres and holds 120,000,000 gallons. The average depth of this reservoir is 19 feet; its sides are well paved, and the top soil has been removed from the bottom to a considerable depth.

Direct Intake.

The direct intake which was approved by the State Board of Health in 1904 comprises a small concrete dam in Portage Creek near the pumping station and a 12-inch intake by means of which water is taken from above the dam directly onto the filters. The dam is of a gravity section and backs the water of the creek under normal flow to a height of about 3 feet above its original level. For the removal of large particles in suspension in the river, screens are provided at the entrance to the 12-inch pipe. No preliminary treatment is provided before applying the water to the filters, as previous analyses had shown that the creek water was frequently very clear and contained but little matter in suspension.

Filters.

The two uncovered slow sand filters provided in 1906 consist of rectangular basins 160 feet long by 68 feet wide, with a total area of 0.52 acre. At 3,000,000 gallons per acre per day, the nominal capacity of the filters is 1,560,000 gallons per 24 hours or 780,000 gallons in 12 hours. The walls of the filters are composed of concrete 12 inches thick, reinforced by buttresses about 16 feet center to center. The bottoms are of concrete 4 inches thick and slope 2 inches from the sides to center where are laid the main collectors. The latter are 10-inch vitrified pipe reducing to 8-inch and finally to 6-inch at the farther end of the filter. The lateral underdrains consist of 4-inch tile pipe, laid 6 feet center to center. As the main collectors were laid with their bells resting on the bottoms of the filters it was necessary to incline the laterals upward at the point where they join.

On the underdrains was placed a gravel collecting system, which comprises 4 inches of broken stones at the bottom, 4 inches of coarse gravel and 4 inches of finer gravel, thus giving a total depth of 12 inches; on this underdrain system were placed 36 inches of filter sand, some of which was obtained from Lake Erie and

*See Plate VII.

some from a local bank. This material was all to be washed and of such size as would satisfactorily fill the specifications prescribed by the State Board of Health in the conditions of approval by that Board. During the special investigation, an average sample of sand was taken from the east filter and was found to have an effective size of .22 m. m. and a uniformity coefficient of 5.9. It was also found to have 10 per cent. loss on ignition, and to contain 2.3 per cent. of iron and alumina oxide. It is evident that the material actually placed in the filters was of unsatisfactory quality, both in regard to its size, and also from the fact that it was not sufficiently washed.

As originally installed, the effluents from the filters were discharged through 8-inch tile pipes leading into the clear well. The end of the effluent pipe was turned up in the clear well to a height of 2 inches above the level of the sand in the filters, as it was intended both to reduce the available head on the filters and also to eliminate possible danger of high rates of filtration. In the spring of 1907, the effluent piping from the filters was changed and an 8-inch cast iron pipe leading directly to the clear well was provided for each filter. These pipes were not turned up at the end.

In the original plans for the filters, the inlet from the creek was a 12-inch pipe and a float valve was provided to automatically govern the height of the water on the filters. This arrangement was also contemplated for the inlet from the reservoir which was through a 12-inch pipe, also, but at a point opposite the inlet from the creek. Neither of the float valves were installed, nor was there any provision made to eliminate the effect of the current of incoming water on the sand in the filter.

Although advised by the State Board of Health, no automatic rate controllers were provided and there is no means at hand to determine either the rate of operation of the filters or the condition of the sand. No provisions are made for washing or storing the dirty sand.

Clear Well.

The clear well for the storage of filtered water is an uncovered concrete basin, 80 feet in diameter and 13 feet deep, with an available storage capacity of 450,000 gallons or a little more than one-half the present daily consumption.

Pumps.

The pumping plant which was built in 1891 and continued in use until the present time comprises two horizontal compound duplex Gordon pumps of 1,500,000 gallons capacity, together with the necessary boilers and appurtenances housed in a substantial stone and brick building.

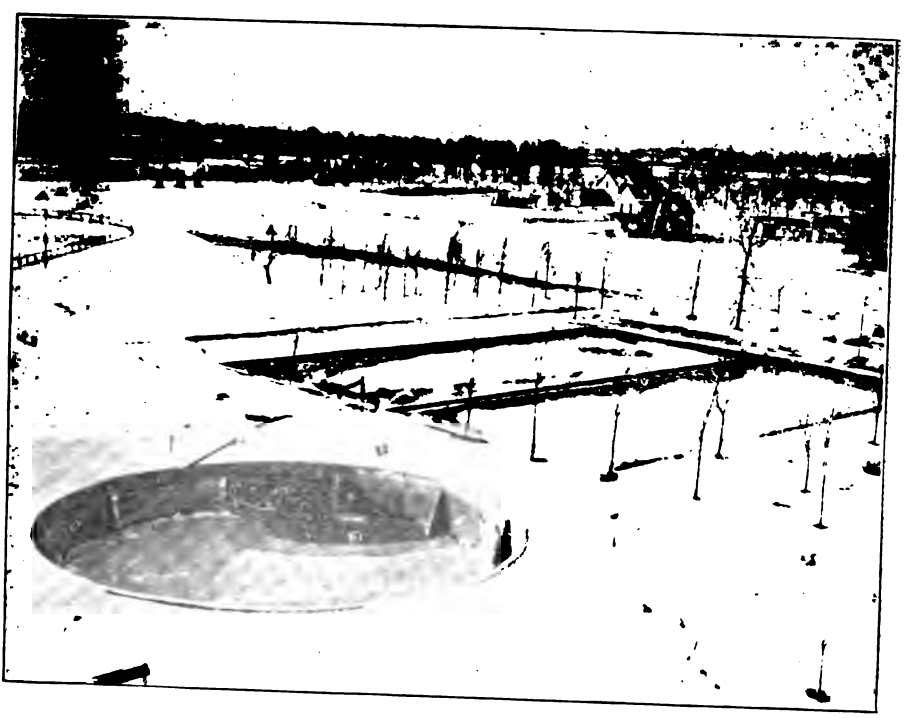
Stand-Pipe.

As the pumps are operated only 10 or 12 hours per day, storage is necessary during the night and is provided by a stand-pipe 25 feet in diameter and 100 feet deep, holding 367,000 gallons. It is placed on a stone tower 65 feet high and gives a pressure of 70 pounds per square inch at the pumps. The average pressure in the distributing system is 60 pounds per square inch.

EXAMINATIONS.

During this investigation the Fostoria plant has been visited on three occasions, January 11th, February 20th, and July 3rd, 1907. On the first and last visit inspections only were made, but on February 20th such samples were taken as con-

Fostoria. — View of Filter During Construction.



Fostoria. — General View of Plant.

sidered necessary to determine the efficiency of the plant. It has been found that the filters have gradually become so clogged as to make their use practically impossible and the development of present conditions has been indicated at each visit. The results of each examination and the features that had then developed will be shown in turn.

INSPECTION OF JANUARY 11TH, 1907.

On January 11th, it was learned that the filters had been first started in operation two weeks previous but they had been out of service for one week and were restarted on the morning of the examination.

The source of the supply was from the direct intake in the creek, which was the only source that had yet been used to supply the filters. While it was stated by the engineer that when first put in service the effluent from the filters was clear and apparently very satisfactory, it was noted that on January 11th the filtered water was somewhat turbid. The river was clearing up and although it contained but a small amount of suspended matter, this was in a very finely divided state such as is very difficult to remove by the ordinary methods of slow sand filtration.

In the absence of controlling devices it was impossible to tell what was the condition of the sand in the filters, or at what rate were the different units operating. It was apparent that even at this early date the city officials were not satisfied with the results obtained by the plant.

EXAMINATION OF FEBRUARY 20TH, 1907.

On February 20th, about one month later, a thorough examination of the Fostoria plant was made and samples were taken to show the efficiency obtained by the filters. (See Table No. 14.)

Methods of Operation.

At the time of the examination, raw water was taken from the creek directly onto the filters without preliminary treatment and the total quantity filtered on February 19th was 776,000 gallons in 24 hours. As the total area of the filters is 0.56 acre, the average rate of filtration was 1,390,000 gallons per acre per day. In the absence of other controlling devices it was necessary to regulate the rate of filtration by the valves in the effluent pipes. These were opened an equal amount and it was estimated that both filters were operating at the same rate.

During the night, when the pumps are idle, the clear well becomes full resulting in the slowing down of the filters as the water rises above the stand-pipe on the effluent pipe, for which reason the rate of filtration is not constant throughout the 24 hours, and the rate above mentioned is not the cosntant but the average rate.

It should also be noted that, from the fact that the pumps operate during the day only, at the close of the day's run the clear well is practically empty and in case of a sudden demand for a large quantity of water at that time, such as would be caused by a serious fire, it would be necessary to turn raw water directly into the clear well. To remove this condition it is necessary either to pump for a longer period of time or to provide greater storage for filtered water.

Character of Creek Water.

The evidence obtained by the analyses shows that the water in the creek had a turbidity of but 80 parts per million, but that it contained a considerable amount of very fine suspended silt which is extremely difficult to remove by slow sand filters.

Duplicate samples were taken for coli, which were found present in 100 c. c. of only one of the samples, a fact which would indicate the absence of any serious pollution of the supply, although the total number of bacteria was large.

Character of Reservoir Water.

The water in the reservoir had been stored for practically six months and it is of interest to note that it contained 75 parts per million turbidity even after such a long period of sedimentation. The suspended matter contained was of very fine silt and it is probable that this was the minimum turbidity which might be expected to result from even a longer period of storage. The water in the reservoir contained only 1,200 bacteria per c. c. as compared with 13,300 per c. c. in the river; while the former contained 45 parts of dissolved color, there were but 15 parts in the river; also, the water in the reservoir was considerably softer than that in the river.

Efficiency of Plant.

The evidence obtained at this examination shows that the filters were removing only 87 per cent. of the bacteria and that while the effluent contained no coli and was potable, yet it carried sufficient turbidity and color to make it of unsatisfactory appearance. It is apparent that the filters were not producing satisfactory results at this time.

TABLE NO. 14.

Fostoria — February 20, 1907.

Field No.	Collected. Hour.	Source.	Bacteria per C. C.	Colon. 1 C. C.	Colon. 100 C. C.	Parts per Million. Col.	Turb.	Alk.
1,039	2.15 P. M.	Tap in force main.....	3,500	0	0	15	30[1]	114
1,040	3.00 P. M.	Raw water from creek.	13,300	0	0	15	80[2]	108
		Raw water from creek for coli only.....	.....	0	+	.....	.....	.....
1,041	4.00 P. M.	Effluent from filters...	1,700	0	0	15	30[1]	108
1,042	4.00 P. M.	Leakage in old filter from tile pipe.....	1,200	0	0	.....	.....	124
1,043	4.30 P. M.	Reservoir	1,200	0	0	45	75[2]	70
1,044	4.30 P. M.	Tap in force main....	3,300	0	0	.....	.....	108

[1] Estimated.
[2] By rod.

Determinations.	Field No. 1040	Field No. 1041	Determinations.	Field No. 1040	Field No. 1041
Free Ammonia	.056[3]	.012[3]	Total solids	250	253
Alb. Ammonia	.184	.120	Loss on Ignition.....	52	40
Nitrites	.003	.002	Chlorine	2.0	1.5
Nitrates	2.0	2.0	Fe	.6	.3
Oxygen required	4.01	3.97			

[3] Parts per million.

Contamination Beyond Filters.

Leakage Into Old Filter. A considerable stream was flowing into the old filter from a tile drain located at about its original water line. This drain was supposed to carry seepage water from the reservoir but the alkalinity of the sample taken would indicate that it was not supplied from the reservoir but from ground sources. The bacterial analyses show that it was not of objectionable character.

Connection to Old Filter. It was learned at this examination that when the pumps are shut down at night, the water rises in the old filter until it reaches the same elevation as that in the clear well and that when the pumps are started on the morning the former is drawn down and emptied. This is due to the fact that the wooden box through which the effluent from the filter formerly discharged has never been removed, and that it, together with the connection from the clear well, discharges into a manhole near the pumping station. An attempt was made to seal this wooden box with cement at both ends, but it was not made tight and the leakage into the old filter from the clear well when full is through this pipe. The analyses indicate considerable contamination between the filters and the pumps, which is probably caused partly through this connection and partly through the poor construction of the effluent pipe from the filters. This pipe is of tile and the ground water stands around it to a considerable depth (generally about two feet below the surface of the ground).

Possible Contamination During Floods. There is a possible contamination of the water in the clear well from the fact that its sides are raised but a few inches above the finished grade of the surrounding ground and, during high stages of the river, raw water will undoubtedly overflow into the well. The sides of the latter should be raised about 3 feet to remove the danger of pollution from this source.

INSPECTION OF JULY 3d, 1907.

Operation Previous to Inspection.

When visited on July 3d, it was learned that the plant had been operated at irregular intervals during which the filters had been supplied with water from the creek. About two weeks previous to the examination the filters had been scraped, after which they had run for about eight days until they became so dirty that no more water would pass through them. When previously cleaned, the maximum period of operation between scrapings had been ten days, and the quantity of water filtered per day averaged approximately 800,000 gallons. It was noted that the riser on the effluent pipes from the filters had been removed, and it was stated that no attempt had been made to clean the filters until it was impossible to get any water through them.

Conditions at Time of Examination.

On July 3d, both filters were out of service and the west filter had been draining for six days. There still remained about 4 inches of water on the surface and no water was flowing through the discharge pipe. The east filter had been scraped just previous to the inspection and its surface was found to be very hard and compact, due in part to the action of the sun which had formed a dry, hard crust to a depth of from 1 to 1½ inches. The engineer stated that, when the filters were scraped, only the layer of silt deposited on the surface had been removed, and at the time of the inspection, although the filters had been

scraped recently, it was apparent that at least ¾ of an inch of sand should be removed.

At this time a special study of the condition of the sand in the filters was made, and an average sample was taken from the east filter, which on analysis was found to have an effective size of but .22 m. m. and to contain considerable organic matter, as was shown by its loss on ignition of 10 per cent. It was apparent, also, that there had not been sufficient care exercised in placing the filtering material, which was unloaded from teams driven directly into the filter and over the material first placed. The sand around the outer edges of the filters settled so that its average depth was about six inches less than that at the center, where it apparently had been compacted by the teams driven over it.

At the inlet to the filters there had been a scouring of the sand by the inflowing water which had caused an excavation in the filtering material to a depth of 2 feet and of considerable length.

The only change that had been made in the construction of the plant since the previous examination was the replacing of the tile effluent pipe by two lines of 8-inch cast iron pipe, each of which discharged into the clear well independently. No controlling devices had been provided and it was apparent that it had been impossible to operate the filters understandingly.

Review of Conditions Causing Poor Results.

At the time of writing this report, the purification plant at Fostoria remains idle, as it is found impossible to operate the filters for a period longer than seven or eight days between scrapings and the results obtained by the plant are not commensurate with the expenses incurred in its operation. The features that have most tended to produce the above conditions, as noted during the special investigation by the State Board of Health, are briefly stated as follows:

First. The absence of preliminary treatment, some form of which has been proven necessary for the successful operation of slow sand filters when the average turbidity of the raw water is greater than 45 parts per million. Although former analyses indicate that the reservoir water is generally sufficiently clear to be efficiently filtered without preliminary treatment, during 1906-07 its turbidity has always been greater than 70 parts per million.

Second. The poor quality of the filtering material which has been shown to be unusually fine and also to contain considerable organic matter.

Third. Lack of sufficient care in placing the filtering material which has been found compacted, particularly in the central portion of the filters, thus causing uneven rates of filtration.

Fourth. The absence of devices for controlling and regulating the operation of the filters and the consequent improper operation of the plant.

Besides the above may be mentioned the following structural features that also increase the difficulty of successfully operating the plant:

First. The absence of covers on the filters.

Second. Leakage into the clear well through the connection to the old filter which at present is necessary as a by-pass for the filters but will eventually be removed.

Third. The possibility of overflow into the clear well during high stages of the river.

Fourth. The absence of facilities for draining the water above the sand in the filters when scraping is necessary.

IMPROVEMENTS NOW CONTEMPLATED.

A firm of engineers have been called upon to consult with the Fostoria authorities as to the best method for improving the present condition of the plant. It has been recommended by the State Board of Health that while some form of preliminary treatment for the preparation of the water for the filters is desirable, immediate attention be given to the installation of regulating devices and gages, which will permit an intelligent operation of the plant; also that some form of sand washing machine be provided and that the sand be removed and washed It is hoped that these improvements will soon be completed in which case it should be possible to operate the Fostoria plant without encountering the present difficulties.

COST OF INSTALLATION.

The cost of the improvements to the Fostoria plant including the construction of the two filter units, the building of an intake, and the remodeling of the clear well was approximately $18,000.

The cost of operation of the plant cannot be stated, as it has been in use at very irregular intervals, but the only additional expense of operation since the improvements were installed is incurred by the labor employed in scraping the filters.

GALLIPOLIS.

Gallipolis, the county seat of Gallia County, is in the south central part of Ohio on the Ohio River. It is a typical river town of the older class, and has little manufacturing. Its population in 1906 was estimated at 5,500.

HISTORICAL.

The Gallipolis waterworks were constructed in 1894-5 and the supply was taken from the Ohio River by an infiltration system.

CONDITIONS LEADING TO PURIFICATION.

The Ohio River has an estimated watershed above Gallipolis of 51,500 square miles, on which there was a total urban population of 1,653,900 in 1900, equivalent to 32 per square mile. There is also a considerable number of small communities located on the watershed along the river, the population of which is not included in the above figures.

The nearest source of pollution for the Gallipolis water supply is Point Pleasant, with an estimated population of 2,000, which is situated at the mouth of the Kanawha River, but one mile above the intake of the Gallipolis waterworks. Point Pleasant has no water supply nor sanitary sewers, but there is a considerable amount of surface and sub-soil drainage, which finds its way into the Ohio River at this point. Although there are several small communities above Point Pleasant, the nearest places of considerable size are Pomeroy and Middleport, with a combined population of 8,600, 17 miles above the Gallipolis waterworks. At these two places there are several sanitary sewers and also a considerable amount of pollution from surface washing. The city of Charleston, with an estimated population of 13,000, is 61 miles above the Gallipolis waterworks on the Kanawha River.

From the above it will readily be seen that the Ohio River water at Gallipolis is not suitable for domestic purposes without purification on account of its pollution. It is also seldom sufficiently clear to be desirable for domestic purposes and during flood stages carries very large amounts of suspended matter.

Preliminary Tests.

The bar in which the intake for the water supply is located is at the head of Gallipolis Island and about one mile above the center of Gallipolis. There is no local pollution of the Ohio River above this point, as the small run which receives the effluent from the sewage filters at the State Hospital discharges several hundred feet below the intake. The bar is composed of well graded gravel ranging in size from 3 inches in diameter to a fine sand. Its location at the head of the island is ideal for assuring both the required amount of water, and also makes it practically impossible for ground water to reach the source of supply. Before installing the intake, a 2-inch pipe about 14 feet long, with a perforated brass point, was driven into the bar, and to it was connected a ship pump. This pump was operated for 24 hours, and it was found that the draft had no effect on lowering the level of ground water in or around the pipe. From this test it was assumed that there would be no difficulty in obtaining the required supply and the four wells composing the intake were then set.

DESCRIPTION OF PLANT.

The construction of the waterworks was begun by the city of Gallipolis in 1894 and finished in 1895. The plant comprises the following features: A specially designed intake, by which filtered river water is obtained from the above mentioned bar; a suction pipe 1,600 feet long leading to the pump well; two pumps, together with the necessary appurtenances; a 10-inch cast iron force main, together with the distributing system, and a reservoir for the storage of filtered water. The pumps and boilers are housed in a substantial brick building, situated near the bank of the river about one mile above the center of Gallipolis.

Intake.*

The intake is of an original design and comprises a series of 4 cast iron wells sunk in the bar, and directly connected to the pumps by a 16-inch cast iron suction pipe, 1,612 feet long. The wells are each 4 feet in diameter and 6 feet high, with 12-inch connections to a common suction pipe. They are sealed, except at the bottoms, which are 13 feet below the bottom of the river. There are 7 feet of material over the top of the wells. At the time of installing the plant there were but 6 feet of material over the top, but at the present time the depth is 7 feet, and is constantly increasing.

By means of a by-pass around the check valve in the main suction, it is possible to back-flush the wells directly from the reservoir. Detailed drawings of the intake are shown in Plate No. VIII.

Sometime after the plant was installed, it was feared that there might be an unequal settlement of the wells, resulting in possible breaks in their connections, and in order to provide against this, 10x10-inch oak timbers were placed under the tees on top of the wells. These timbers are perfectly preserved at the present time.

Test of Intake. After the plant was installed, an 8-inch steam pump was connected to the wells and operated continuously for twenty days with no noticeable effect on the level of the ground water in the bar. During a period of

*See Plate VIII.

low water in September, 1905, another test was made in order to determine the effect of pumping on the level of the ground water around the wells. A series of stones were set at intervals on a radius of 500 feet from the wells with their tops 2 inches below the level of the water in the river. Twenty minutes after starting the pumps, the water had lowered 7 inches below the top of the stones, or a total amount of 9 inches. After this point was reached, apparently the flow of river water to the wells was established and no further decrease in its level was noted.

Pump Well.

The 16-inch cast iron suction terminates in a pump well 16 feet in diameter by 45 feet deep, in which is located the water end of the pumps. The steam ends are approximately 45 feet above the bottom of the well in the main room of the pumping station.

It was originally intended to carry the bottom of the pump well to a point at least 10 feet lower, but on account of a serious accident during the construction, this was not done.

Pumps.

The suction pipe is directly connected to the pumps, which are two vertical compound duplex Gordon pumps of 720,000 gallons capacity each in 24 hours. A 10-inch cast iron force main carries the water from the pumping station to the reservoir, about two miles distant, and so located that the water has to pass through the center of the city on its way to the reservoir, thus insuring a good circulation in the mains.

The ordinary suction lift when pumping 300,000 gallons per day of 10 hours is about 18 feet and the pressure in the force main to the reservoir is then 110 pounds. The maximum quantity of water which has yet been pumped at Gallipolis is 600,000 gallons in 10 hours, at which time the suction lift was 27 feet and the pressure in the force main 140 pounds.

Reservoir.

The reservoir is located on a hill back of Gallipolis, 324 feet above the bottom of the pump pit. It is a brick and concrete basin, 280 feet long by 85 feet wide by 15 feet deep, and has a capacity of 2,300,000 gallons. By means of a drain in the bottom it is possible to clean the reservoir, and at such times the supply is pumped directly into the mains without danger from breakage, as a relief valve is provided in the force main opposite the pumping station.

OPERATION.

The operation of the Gallipolis waterworks has been very similar to that of those plants which use the Ohio River direct, except that for some time after first starting the plant in service, it was the custom to frequently back-flush the wells from the reservoir. It has subsequently been thought that this may not have been necessary, but the Gallipolis officials feared that the sand layers over the intake might become clogged from constant use, and it was to avoid this that the wells were back-flushed. It is only at low stages of the river that it is possible to manipulate the valve by which water from the reservoir is by-passed around the check valve in the suction.

The plant was first started in operation during the dry season of the year when the bar was uncovered, and it was then the custom to flush the wells several times a week, for which purpose approximately 70,000 gallons of water from the

reservoir under 120 pounds pressure were used. There was such a considerable deposit of very fine material on the bottom of the river over the wells after flushing that it was necessary to employ teams and scrapers for its removal. In recent years this custom of flushing the wells has been abolished, and on several occasions when the material over the wells has been examined it has been found very clean and practically free from fine material. It was also found that beneath the wells the filtering material has assumed the form of an inverted cone, with sides sloping approximately 30 degrees to the horizontal.

From the fact that clear water is handled by the pumps, a considerable less expense has accompanied their continued operation than has been the experience where unpurified river water has been used. Ordinary hemp packing is used and has to be replaced only about once a month.

CAPACITY OF THE PLANT.

The average daily consumption at Gallipolis has varied considerably during 1906 and 1907, the extremes noted being 240,000 and 467,000 gallons. There has been a considerable increase in the amount of water pumped during the fall of 1907, and throughout October, the average daily consumption was 467,000 gallons. Of this amount the State Hospital for Epileptics has used from 150,000 to 200,000 gallons. With the increased demands on the plant it has been found economical and desirable to operate both pumps at the same time, and it has been noted that the cost of operation is but slightly increased over that when smaller quantities are pumped.

The actual capacity of the Gallipolis plant is probably limited by the suction lift of the pumps, which, as previously noted, is greater than was intended from the fact that the bottom of the pump well was not carried as low as was first considered advisable. The maximum suction lift of the pumps has been found to be about 28 feet, at which time water was furnished at about 60,000 gallons per hour. The corresponding rate of filtration through the sand beneath the wells is 20 gallons per square foot per minute, which is not very different from the maximum rate as determined by experiments at the infiltration plant at Owensboro, Ky.

During the dry seasons of the year, when the wells were uncovered, it has been found necessary to dig ditches to convey the water from the river over the wells. During the winter, also, some trouble has been experienced in obtaining sufficient water on account of the ice gorges which form at the head of the island and dam the water back from the intake. These have been removed with dynamite. It is stated, however, that at no time has it been necessary to pump water directly from the river.

EXAMINATIONS.

During the special investigation, the waterworks of Gallipolis have been visited on four occasions. July (25-6), November (21-2), 1906, May 15 and November 5, 1907. Regular examinations, during which samples of the river and filtered water were collected, were made on the first three instances, while on November 5, 1907, only an inspection was made. In general it may be said that in these examinations it was endeavored to obtain evidence as to the quality of the Gallipolis water supply, and also information relative to its source as to whether it was obtained from the river or from the ground.

CHARACTER OF RIVER WATER.

During the examination of July 25, 1906, the Ohio River was at about a 10-foot stage and the river bottom over the wells was just uncovered. It was noted that the Kanawha River was in flood, and that the Ohio was turbid and rising. As it was thought that the Kanawha probably was not thoroughly mixed with the Ohio at the comparatively short distance below its point of discharge into the latter, samples were taken from both sides of Gallipolis island opposite the wells, and from their analyses it will be seen that they differ materially in regard to bacterial content. That there is considerable pollution brought into the Ohio by the Kanawha River is shown by the high bacterial content, and by the presence of coli in one c. c. of the water on the east side of the island.

On the examination of November 26, 1906, the wells were covered with about 10 feet of water and the river was rising. On account of the high flow in the river it was not practicable to obtain samples from both sides of the island and one was taken over the wells. It will be noted that the turbidity of the river water was not very great, which was due to the fact that there had been a considerable period of comparatively high water, under which conditions the river valley was washed out. From the fact that the water in the river was softer than in the reservoir, it was also apparent that the river was rising. It will be noted that there was an unusually large number of bacteria in the river, and also some pollution, as indicated by the presence of coli in 100 c. c. The color was found to be 25 parts per million, a quantity which is unusually high for Ohio River water, and doubtless occurs only during the fall of the year when the river receives a large amount of decaying vegetable matter.

During the examination of May 15, 1907, the river was at practically the same stage as at the previous examination, but its current was very much slacker. Two samples were taken, one from either side of the island, and were found very similar in regard to chemical and bacterial content. The number of bacteria was unusually low, but the presence of coli in 100 c. c., indicates a slight amount of pollution. It will also be noted that the dissolved color was low, as would be expected at this season of the year.

A review of the analyses of the samples of river water at Gallipolis indicate that it is always unfit for domestic use without purification, because it always contains some pollution and objectionally large quantities of suspended matter and frequently contains very large amounts of suspended matter. Chemically, it has been found soft as compared with other rivers in Ohio, and to contain but little dissolved color.

SOURCE OF SUPPLY.

The question of the source of the Gallipolis supply is one that has interested every one familiar with infiltration plants, and it has frequently been stated that undoubtedly a large part of the water was obtained from the ground and not from the river. This point can be determined only by a comparison of analyses of the river water and of the supply as obtained, particularly in regard to their relative hardness. The evidence obtained during the examination indicates but little difference between the alkalinity of the river and that of the water as pumped, which of itself would indicate that little, if any, ground water was obtained. On July 26, 1906, a sample was taken from a dug well, about 1,000 feet from the river and nearly opposite the intake of the waterworks, and analyses show that this ground water had an alkalinity of 216 parts per million, as compared with 46 parts per million, the alkalinity of the river water at the same time. This is conclusive evidence that at that time there was no ground water pumped.

The greatest difference found between the river water and that pumped was on May 15, 1907 From the fact that there was then a considerable variation in the river water on the two sides of the island, it is apparent that the character of the river water was rapidly changing, and the results of the analyses indicate that these changes had not yet effected the supply.

In the light of the evidence of the various examinations, it is apparent that the supply for Gallipolis is obtained by filtering river water and not from ground sources, even during low stages of the river.

CHARACTER OF FILTERED WATER.

The evidence obtained at the various examinations shows that the water supply is wholesome at all times, as it contains very few bacteria per c. c. and in but one instance has it been found to contain coli even in 100 c. c. On May 15, 1907, coli were present in 100 c. c. in two samples obtained from a tap at the pumping station, but these results probably are not significant, as a sample from the reservoir contained but 32 bacteria per c. c. and no coli in 100 c. c. In general it may be said that the Gallipolis water supply has always been very satisfactory for domestic purposes, is comparatively soft, and of very good appearance. That it is potable is indicated also by the absence of typhoid fever among the consumers.

SUMMARY.

The Gallipolis plant has successfully met the expectations of the designers in that it has always furnished a satisfactory supply at no greater expense than that required to furnish untreated river water, and on this account it has attracted considerable attention among those interested in public water supplies. It has frequently been desired to use this system in other places, but it should be understood that special conditions, both of location and filtering material are required for the successful operation of such a plant. The location of the Gallipolis intake at the head of Gallipolis island is such as to make it impossible to draw on ground water sources even during low stages of the river, and, moreover, the fact that there is a comparatively high flow of water in the stream tends to keep the bar clean. Both of these features, together with a natural bed of well graded, clean gravel are essential for the successful operation of such a plant as that at Gallipolis.

COST OF INSTALLATION.

In the following table is shown the cost of installing the Gallipolis waterworks. The total original cost of the plant was $87,000, for which bonds were issued at 5 per cent., and no sinking fund was provided. The above figure includes also the cost of the distributing system which comprised a total of 9 miles and 698 feet of mains subdivided as follows:

16"	1,612
12"	2,768
10"	8,719
8"	14,529
6"	15,831
4"	4,759

The total cost of the plant exclusive of the distributing system was $29,600, as follows:

COST OF PLANT.

Intake and suction	$5,400
Pump well	1,000
Pumps and boilers	8,700
Buildings for pumps and boilers	4,500
Reservoir	10,000
Total	$29,600

COST OF OPERATION.

In the following table is shown the cost of operating the Gallipolis plant from April 1, 1906 to April 1, 1907. These figures indicate no cost other than would be incurred in the operation of a plant handling river water direct without purification. The cost per million gallons is perhaps high, but the plant was run at only 40 per cent. of its total capacity and it is probable that the total expense of operation would be but little greater if the present daily consumption were at the maximum capacity of the plant.

SALARIES		$2,520
Superintendent	$1,200	
Engineer	720	
Clerk	600	
LABOR		929
Fireman ($1.80 per day)	390	
Other Labor	539	
SUPPLIES		1,727
Coal (656.2 tons at $1.516 per ton)	995	
Supplies and Repairs	535	
Light	17	
Postage and stationery	86	
Incidentals	94	
TOTAL		$5,176

Total number of days pumped (10 hrs)	322
Total number of gals. pumped	94,596,125
Total number of lbs. coal consumed	1,312,400
Average number of lbs. coal consumed per day	4,075
Total number of gals. pumped per lb. coal	72.078
Average total cost per million gallons	$54.70
Average lbs. coal per million gallons	13,900

TABLE NO. 15.

Gallipolis — Results of Analyses During Examinations.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria per C. C.	Colon. 1 C. C.	Colon. 100 C. C.	Parts per Million. Col	Tur.	Alk.	Inc.	Tot. Hard	CO_2
			July 25-26, 1906.					(a)		(b)		
		P. M.										
285	7-25	3:00	River, west side..	11,000	0	0	.....	525	46	95	141	.....
286	7-25	3:10	River, east side..	40,000	+	+	.....	.....	46	77	123	.....
			Average	25,500	.....	.....	.....	525	46	86	112	.....
		A. M.										
284	7-25	11:45	Tap at pump.....	75	0	0	0	2	46	59	105	.....
		P. M.										
287	7-25	3:35	Tap at pump.....	43	0	0	0	.....	45	62	107	.....
		A. M.										
291	7-26	9:20	Tap at pump.....	46	0	0	0	2	38	78	116	.....
			Average	55	0	0	0	2	43	66	109	.....
		A. M.										
289	7-26	8:00	Reservoir	29	0	0	0	3	42	57	99	.....
290	7-26	8:45	Tap in waterworks office	39	0	0	.....	0	.....	59	.....	.....
		P. M.										
288	7-26	4:30	Well on fair grounds	.....	.....	.....	.....	.....	216	.....	.....	.....
			Nov. 21, 1906.									
		A. M.										
825		7:30	River, west side..	250,000	0	+	25	350	39	24	63	.....
826		8:00	Tap at pump.....	260	0	0	6	<5	39	32	71	.....
827		9:00	Tap at pump.....	.....	0	0	6	<5	39	.....	.....	.....
830		11:00	Tap at pump.....	.....	.....	.....	6	<5	38	.....	.....	.....
		A. M.										
828		9:30	Reservoir	.....	0	0	6	<5	46	.....	.....	.....
829		10:30	Tap at waterworks office	140	0	0	6	<5	42	.....	.....	.....
			May 15, 1907.									
		A. M.										
1301		9:30	River, west side..	2,700	0	+	.....	60	28	.....	.....	.....
1302		9:45	River, east side..	2,000	0	+	10	75	24	.....	.....	8
			Average	2,350	.....	.....	10	67	26	.....	.....	8
		P. M.										
1306		2:00	Reservoir	32	0	0	6	<5	35	.....	.....	.....
1305		1:00	Tap at waterworks office	55	.....	.....	6	<5	34	.....	.....	.....
		A. M.										
1300		8:30	Tap at pump.....	110	0	+	4	<5	36	.....	.....	5
1303		10:00	Tap at pump.....	130	0	0	4	<5	33	.....	.....	.....
1304		11:00	Tap at pump.....	.....	0	0	4	<5	33	.....	.....	.....
		P. M.										
1307		3:00	Tap at pump.....	50	0	+	4	<5	32	.....	.....	.....
			Average	96	.....	.....	4	<5	33	.....	.....	5

(a) Turbidity of (285-286) combined. (b) On filtered samples.

TABLE NO. 15 — Concluded.

November 21, 1906

Parts Per Million.

Sample No.	Oxygen Req.	Alb. Ammonia	Free Ammonia.	Nitrites.	Nitrates.	Chlorine.	Alkalinity.	Incrustance.	Tot. Hard.
825	14.20	.258	.052	.006	trace	42.20	39	24	63
826	.57	none	trace	trace	none	19.80	39	32	71

GENEVA.

The village of Geneva is in Ashtabula County, about ten miles from Lake Erie and forty-five miles east of Cleveland. Its population in 1906 was estimated at 2,500. While there are a few small manufacturing establishments in Geneva, it is the center of a farming district and would be considered a residential rather than a manufacturing town.

HISTORICAL.

In 1902 the question of a water supply for the village was first considered and it was found that there were two possible sources, one from the Grand River, and one to be obtained by impounding Cowles Creek. A study of the latter showed that, above the proposed site for a storage dam, there were 100 people residing on the watershed of the creek which received the run-off from but 3.1 square miles. On account of the small size of the drainage area of Cowles Creek and also the great difficulty of preventing its possible pollution, it was considered advisable to use Grand River as a source of supply.

The area of the watershed of the Grand River above the site of the pumping plant is 325 square miles and the lands along the sides of the stream generally have steep slopes, the majority of which are cultivated. At Mechanicsville, about 15 miles above the site of the pumping plant, there are extensive swampy areas which are always flooded and which cause a considerable amount of dissolved color in the river water. There are no towns with a population greater than 500 on the watershed of which the average rural population was estimated in 1900 at but thirteen per square mile. In general it may be said that the population on the watershed above the Geneva waterworks is lower than that of any other watershed in Ohio. From samples analyzed in the laboratory of the State Board of Health, it was found that the river water was potable from a bacteriological standpoint, but that the considerable amount of suspended and dissolved matter in the river made it undesirable as a domestic supply without purification.

At a point about three and one-half miles south of the center of the village, near Rogers Corners, there was an old mill where a water-power had been developed, and it was at this point that the pumping station and filtration plant were built. A timber crib dam had been provided to divert water into a head-race, about 800 feet long, at the end of which on the site of the old mill, the pumping station was located. The construction of the plant was completed in September, 1902.

DESCRIPTION OF PLANT.

The main features of the plant comprise an intake, raw water pump, coagulating system including coagulating and solution tanks, a gravity mechanical filter, clear well, power pumps and distributing reservoir. (See Plate IX.)

Intake and Raw Water Pumps.

From the intake, a concrete conduit carries the water by gravity to a suction well, from which it is pumped by a 5-inch, Worthington, conoidal, centrifugal pump placed in the basement of the filter house. This pump raises the water through a 6-inch pipe into the sedimentation tank just outside the filter house.

Coagulating Tank.

The sedimentation or coagulation tank is an uncovered wooden tub, 24 feet in diameter, with an available depth of 17 feet, holding 52,800 gallons. There are no baffles in the tank and a circular motion is imparted to the water by a horizontal elbow on the discharge from the raw water pump. At the usual rate of pumping, approximately 378 gallons per minute, the length of storage period is 140 minutes or two and one-third hours. In the bottom of the tank is an 8-inch drain for flushing purposes. The inlet is in the side about 6 feet above the bottom, while the outlet is also in the side 3 feet 4 inches below the top.

From the basin the water flows by gravity on to the filter, the top of which is 2 feet 4 inches below the top of the coagulating tank.

Solution Tanks.

Aluminum sulphate is used for a coagulant. It is dissolved and stored in two solution tanks, each 4 feet in diameter by 6 feet deep, holding 564 gallons. From the storage tanks, the solution flows by gravity to a ball cock tank and thence into the suction of the raw water pump. The rate of flow is indicated by a gage-board, the indicator of which is operated by a float on the tank.

Filter.

The filter is of the New York type and consists of a wooden tank 16′-8″ in diameter, with an area of 218 square feet, or 0.00500 acre. In the bottom of the tank is the strainer system which comprises 152 cone valves connected to a manifold of wrought iron pipes. Detail drawings of the valves and manifolds are shown in Plate X. The system is made up of four distinct units and by means of a four-way valve in the center, any one of the quarters may be used alone during washing, or the entire area may be washed at one time.

On the strainers is placed the filtering material which consists of four feet of sand, having an effective size of .53 m. m. and a uniformity coefficient of 1.4.

The filter is washed with water obtained directly from the force main. It is necessary to operate the power pumps during washing as the pressure from the reservoir is not sufficient to give the required amount of water. There are no mechanical agitators but the quarter wash system, by which one-fourth section of the filter may be cleaned at a time, is provided to give such a rapid application of the wash water that mechanical agitation should be unnecessary. The dirty wash water is carried away by an annular trough of sheet metal of triangular section 12″ wide on top and 11″ deep.

A Weston automatic rate controller is provided, which, however, is not of the right size as the disc is too small and the controller has not been in use since originally installed. No loss of head gage is furnished.

Clear Well.

The clear well is a stone masonry basin contained within the foundation walls of the filter house. It is 23'x39'x8½' deep, with a capacity of 40,000 gallons. At the usual rate of pumping, 378 gallons per minute, the length of the storage period for filtered water is 106 minutes. The total available head on the filter, when the clear well is full, is 14 feet.

Pumps.

From the clear well, the water is pumped to the distributing reservoir by two triplex, single-acting, power pumps built by the Deane Steam Pump Company of Holyoke, Mass. Each pump draws water directly from the clear water reservoir through an 8-inch suction pipe and discharges it into the 8-inch force main leading to the reservoir. Each has a nominal capacity of 525 gallons per minute, or 756,000 gallons per twenty-four hours, and works against a head of about 110 feet.

To drive the pumps, a 40-inch vertical Sampson turbine, made by James Leffel & Company of Springfield, Ohio, is installed in a wheel pit beneath one corner of the building. It is supplied with water from the race under a head of about 9½ feet and makes 100 revolutions per minute, developing about 75 horse power. During the dry seasons of the year, there is not a sufficient supply of water available in the river to use the turbine and an auxiliary gasoline engine is provided to drive the pumps at such times. It is a 50 H. P. "New Era" gasoline engine made by the New Era Iron Works Company of Dayton, Ohio, and was installed on the opposite side of the room from the turbine, connected to the main shaft of the pumps. The latter are between the engine and the turbine, either of which may be cut out as desired.

Distribution Reservoir.

The distributing reservoir is about 3,500 feet from the pumping station and about three miles distant from the center of Geneva. The full reservoir level is 104 feet above the floor of the engine room and 180 feet above the level of the village. The reservoir, which is made partly in excavation and partly in embankment, is 220 feet square at the inside of the top and has a capacity of 2,800,000 gallons. It was excavated in a stiff clay formation to a maximum depth of about 6 or 7 feet and the top of the embankment is 4 feet above full reservoir level. The sides are of rolled embankment lined with 18 inches of clay puddle and covered with one course of paving brick laid on 3 inches of screened gravel. A concrete toe wall, 18 inches high by 12 inches wide, extends around the bottom of the inside slope and acts as a footing for the brick paving. The floor of the reservoir is covered with 18 inches of puddle.

Water is fed into the reservoir through an 8-inch branch from the force main and the inlet is located about 25 feet either way from the southeast corner. The outlet is in a similar position with reference to the northeast corner. Both are practically level with the bottom of the reservoir so that the water is introduced into and taken from the reservoir at the bottom. The pipes and valves are so arranged that it is possible to cut out the reservoir and pump directly into the force main leading to the village.

In the original report of the engineer of the State Board of Health it was recommended that the reservoir be constructed with two independent compartments for cleaning purposes but this was not done and when, in June, 1906, it was found necessary to remove some objectionable growths and to clean the reservoir, it was accomplished with considerable danger not only from lack of storage of water for fire protection but also from the difficulty in regulating the pressure while pumping directly into the mains.

EXAMINATIONS.

During the special investigation the plant has been visited six times as follows: May 24th, June (22-27), September (13-15), 1906, (January 31-Feb. 2), August (9-10) and December 11th, 1907. Inspections of the plant were made on the first and last of these visits, but on each of the four intermediate visits regular examinations were made.

OPERATION.

One engineer is employed to operate the plant which is generally started at about 5:00 a. m. and continued in service until a sufficient quantity of water has been pumped. This requires from eight to fourteen hours. During the greater part of the year there is a sufficient flow of water in the river to drive the turbine, and during 1907 it was necessary to use the gas engine but twenty-one days. The plant generally requires very little attention as the method of operation consists in pumping the raw water, to which the coagulant has been applied, into the preliminary basin, from which it flows by gravity through the filter into the clear well and is lifted by the power pumps into the distributing reservoir.

Until the fall of 1907, the raw water pump had not worked satisfactorily and it had been impossible to supply the filter at a rate equal to that at which the water was pumped to the reservoir, on which account it was necessary to operate the filter fourteen hours to obtain such a quantity of clear water as was handled by the power pumps in eight hours. In the fall of 1907, however, it was found that the discharge of the raw water pump had been clogged with a wooden plug used when the pump was first installed and when this plug was removed no further trouble was experienced in maintaining the filter and power pumps at approximately the same rates, and the length of time required to operate the plant has been from eight to ten hours.

There are no counters on the pumps and it has been impossible to make an accurate estimate of the number of gallons filtered daily, but as the turbine and gas engine are generally operated at approximately a constant speed, the quantity of water treated varies with the length of time during which the pumps are operated. The average quantity of water pumped per day is probably not far from 250,000 gallons.

From the fact that the operator of the plant has been changed several times and also that the plant was destroyed by fire in the winter of 1907, it has been impossible to obtain regular daily records showing the operation of the plant.

Application of Coagulant.

In preparing the coagulant solutions, a charge of from 30 to 60 pounds is placed in a perforated box in the top of the storage tanks and water is passed through it into the storage tank below where the solution remains until required. Each tank is used in turn and the coagulant in each tank is generally sufficient for about 8 hours run. The solution is applied at a constant rate corresponding to one-quarter inch drop per minute in the tanks and the amount of coagulant applied is varied by changing the charge.

No accurate records are kept of the amount of coagulant used, which has varied from 2 to 5 grains per gallon, but it is probable. that the average quantity of alum applied is approximately 3 grains per gallon.

Quality of Alum Used.

On the examination of January 31-February 2, 1907, a poor coagulation of the water applied to the filter was observed and was thought to be due in part to the comparatively small amount of suspended matter in the raw water and in part to the poor quality of the alum used. A sample of the latter was analyzed and found to contain 16.48 per cent. alumina, of which 1.76 per cent. was in excess of that required to combine with the sulphuric acid present. In accordance with the advice given at this examination, a better grade of coagulant has subsequently been used, and an analysis has shown that the alum used at the time of writing this report contains 18.24 per cent. of alumina of which 2.46 per cent. is in excess of that required to combine with the sulphuric acid. Although somewhat more expensive, this alum has proven very much more satisfactory and no trouble has since been experienced in obtaining a good coagulation.

Coagulating Basin.

The use of the coagulating basin requires but little comment as it simply provides storage for the completion of the chemical reaction of the coagulant. There is a difference in elevation of 27 inches between the top of the tank and that of the filter, and previous to the examination of August 9th, 1907, it had been the custom to maintain the proper elevation of the water on the filter by throttling the valve of the discharge pipe from the coagulating basin, which was kept nearly full. On August 9th it was suggested that by opening this valve wide and allowing the water to stand at approximately the same elevation in both tanks, there would result a less breaking up of the coagulated masses in the applied water. This method of operation would allow a somewhat shorter period for the coagulation of the applied water but it was thought that a greater advantage would result from maintaining the well formed coagulation.

Filter.

Rate of Filtration. At the first examination it was learned that the rate controller had never been in use and it appeared that the disc, by which is determined the size of its orifice, was too small. In January, 1907, this disc was replaced by one of larger size which, however, was still of too small diameter. After the fire of February 22, 1907, the controller was submerged and when the water in the clear well froze, its outer casting burst and has not been replaced.

In the absence of the automatic controller the filter is regulated by the valve in its discharge pipe and as the raw water pump is operated at practically a constant speed, it is necessary to open the effluent valve from time to time as the filter becomes dirty. During the examinations it has been found that the average rate maintained has been approximately 120,000,000 gallons per acre per day.

Washing. On account of the large available head on the filter, no difficulty is experienced in always obtaining a sufficient quantity of filtered water and the necessity for washing is generally noted by a marked turbidity of the effluent. There are occasionally short intervals of time at the end of a run when the effluent from the filter is somewhat turbid, although analyses show that at such times the bacterial removal is as great as when the effluent is clear. The finely divided suspended matter is apparently more difficult to remove than the bacteria.

Various methods of washing the filter have been tried but until the fall of 1907 the quarter method of washing the filter has not been successfully used.

The gutter is flooded when the rate of application of the wash water over the entire area is 6¼ inches per minute, and when the filter is washed at this rate it generally requires about 26 minutes application of wash water, corresponding to 12 vertical feet, or 20,000 gallons of water per wash. Although considerably higher rates of application have been tried, from experience at a similar plant at Newark they are not advised, as there is danger of distorting the plates of the strainer system and a consequent leakage of sand from the filter. The quantity of wash water necessary has been practically the same no matter what its rate of application. The total amount of wash water used is large and is due to the absence of mechanical agitation and also to the insufficient preparation and sedimentation of the water applied to the filter.

On the examination of August 9th, 1907, the sand was found in very poor condition and to contain many hard spots where it had caked together with clay, and also to have settled away from the sides of the tank around its entire circumference. At this examination it was suggested that a bar be used to work over these hard spots while washing and a considerable improvement of the sand was soon effected in this manner.

On the inspection of December 11th, 1907, it was learned that the quarter method of washing was in use but that it was found necessary to turn off the wash water when changing the quarters. One hour's time is required to wash the filter in this manner. That it is more efficient, however, is apparent from the fact that the sand is well agitated and that all the hard spots are removed.

In the absence of daily records no accurate estimate of the amount of wash water necessary to operate the Geneva plant can be obtained but it is probable that the filter has been washed on an average twice daily using 40,000 gallons of water for each 250,000 gallons filtered. This corresponds to the use of 16 per cent. of wash water. During such times as the river is turbid, approximately 25 per cent. of wash water is necessary from the fact that there is not a sufficient sedimentation in the coagulating basin and too great a load is then carried by the filter.

Destruction of Building by Fire, February 22, 1907. On February 22, 1907, all of the wooden portion of the pumping station was entirely destroyed by fire and the plant put entirely out of service. Temporary pumps were erected outside the foundations of the building and the supply maintained in this manner for about four weeks until the power pumps could be repaired. The machinery of the plant was not seriously injured, and the only new parts required were the bushings which had been melted. It was necessary, however, to replace the staves in the filter as well as to rebuild all of the wooden portion of the building and it was six weeks after the destruction of the building before any water was filtered. During this time the consumers were notified by the daily press that all water used for drinking purposes should be boiled. On the examination of August 9th, 1907, the plant had been entirely restored and was operating in the usual manner.

Cleaning of Reservoir.

Considerable trouble has been experienced by growths in the distributing reservoir and also by the annual appearance in the spring of large numbers of polliwogs. In June, 1906, at a special request by the Geneva officials, an examination of the reservoir was made with a view to determine whether its cleaning was necessary. It was found that its sides and bottom were covered with a luxuriant dark green growth of fresh water sponge about two inches deep, in which were living great numbers of polliwogs. Considerable feeling had been aroused among the water consumers from the fact that in several instances these polliwogs had been drawn from service taps. As the river was in a low

stage, it would be necessary to refill the reservoir with water pumped with the gasoline engine by the use of which the regular cost of operation of the plant was increased about $4.00 per day, on which account the Board of Trustees wished to defer the cleaning until there should be more water in the river. From the fact that there had been so much dissatisfaction among the consumers and that cleaning was evidently necessary from the foul appearance of the reservoir, it was decided that it should be cleaned no matter what the expense incurred.

On the evening of June 17th, several fire hydrants were opened and on the following day when the water in the reservoir had been lowered about 5 feet, the sides were scraped by hoes and the dirty material removed with baskets. The water in the reservoir was then further lowered until but one foot of storage remained and the cleaning of the sides continued. It was found that the bottom was covered with a similar growth and also contained several patches of growth similar to chara. As the bottom was only covered with 18 inches of clay puddle and not paved, it was soft, making it impossible to complete the cleaning without draining the reservoir. This was subsequently done and the foul matter removed with baskets.

This emptying of the reservoir was accompanied by a considerable danger from breakage of the mains, as it was necessary to pump direct and bi-pass the reservoir and no relief valve had been provided. A gage was provided near the center of the town and carefully watched at all times, so that when the pressure in the mains increased, relief was afforded by opening fire hydrants. Also, in order to decrease the amount of water pumped, one of the cylinders of the power pumps was disconnected.

It was found that the screen protecting the outlet of the reservoir had been placed flush with the reservoir bottom, and when covered with growths had broken by the increased pressure so that polliwogs were drawn into the distributing system. When the reservoir was cleaned a new screen was constructed and the outlet raised 18 inches above the bottom.

Previous to June, 1906, although the reservoir had been in use since February, 1903, it had never been cleaned. In October, 1903, the water was drawn down to a depth of approximately 3 feet and the growth on the sides swept onto the bottom but no material was actually removed from the reservoir. In October, 1904, the water was again drawn down and the sides cleaned. It will thus be seen that the bottom of the reservoir had never been cleaned until June, 1906.

An examination of the reservoir was made during the visit of August, 1907, and it was found that its sides were again covered to a depth of about one inch with a growth of fresh water sponge, extending over the bottom also. A sample of the water in the reservoir was found to contain a considerable amount of sponge growth which was also present throughout the plant and in the raw water.

The reservoir has been treated twice since cleaned in June, 1906, once in the fall of 1906 and again in the spring of 1907, using 20 pounds of copper sulphate applied directly from a boat. The sulphate was placed in a bag and dragged around the reservoir near the edge until all dissolved. The sponge-like growth was probably retarded but not removed and it will probably be necessary to again clean the reservoir in the summer of 1908. Although large numbers of polliwogs again appeared in the spring of 1907, no trouble was experienced from their getting into the mains.

CHARACTER OF RAW WATER.

During each examination of the Geneva plant, samples of the raw water were taken from a man-hole in the conduit leading to the pump well. One of the most striking points in the analyses of these samples is the absence of coli even in 100 c. c., and it is of interest to note that no coli were found in any samples taken during the examinations at Geneva with the exception of one from the Tuttle House on August 10th, 1908. The absence of coli is undoubtedly due to the sparse population on the watershed which, as previously noted, contains but 13 inhabitants per square mile, the least number on any watershed in Ohio.

In nearly all the samples of raw water considerable numbers of microorganisms of various kinds have been found, particularly during the warm season. These have not caused tastes and no odor is noticeable except when the water is heated, when it is decidedly musty. The appearance of fresh water sponge in the raw water has been the cause of the similar growth on the sides of the reservoir and it will be impossible to eliminate this growth from the reservoir until it has been previously removed from the raw water.

The bacterial content of the river water has generally been fairly low and the only examination that requires particular comment is that of January 31st which followed a heavy rain and during which the river was clearing up as shown by the considerably lower alkalinity of the sample taken from the mains. At this examination, although the river contained little suspended matter, the bacterial content was unusually high, varying from 135,000 to 5,000 per c. c. The very rapid decrease in bacteria, and the continued low turbidity of the raw water indicate that the high bacterial content had continued beyond the crest of high water in the river. Generally the river water has been found soft and the occasional low alkalinity would indicate the necessity for considerable care in the use of alum in order to avoid its appearance in the filtered water.

In general it may be said that filtration of the Grand River is necessary only for the improvement of its physical appearance as there is no evidence of pollution on its watershed.

EFFICIENCIES.

Guarantee.

The contract for the installation of the Geneva plant contains the guarantee that the filter maintain an average efficiency of bacterial removal of not less than 95 per cent. when there are 3,000 or more bacteria per c. c. in the raw water, and that there shall not be more than 150 bacteria per c. c. in the effluent when the raw water contains less than 3,000 per c. c.; also that the filtered water shall be clear and colorless.

Coagulating Basin.

There has been considerable variation in the efficiency of bacterial removal by the basin, which removal has varied from 44 to 80 per cent. while the turbidity of the water applied to the filter has varied from 20 to 75 parts per million. Generally the highest bacterial efficiency has occurred together with the greatest removal of suspended matter. The poor efficiencies are in part due to the rotary motion imparted to the water as it leaves the inlet, which motion allows but little deposition of suspended matter in the tank.

On the first two examinations the poor results obtained were in part due to the poor quality of alum used and it will be noted that, on the examination

of August 9th, there was a very satisfactory preparation of the water for the filter due largely to the use of a better grade of coagulant.

In general it has been found that the water on the filter has been well coagulated but that there has been too little removal of suspended matters by the coagulating basin, on which account an unnecessary burden has been thrown upon the filter, causing the use of large amounts of alum and wash water. Moreover, at times it has been found impossible to obtain a satisfactory bacterial removal by the filters, a fact which was due at least in part to the insufficient preparation of the applied water in the coagulating basin. Greater economy and ease of operation would result if there were provided a longer period for the coagulation and preparation of the water for the filter.

Filter.

The analyses indicate a satisfactory bacterial removal by the filter except on the examination of February 1st, 1907. The poor results were due to the poor efficiencies obtained by the coagulating basin caused by the use of a poor grade of alum. That the poor results then obtained were temporary only is shown by the low bacterial count of the sample from the mains.

Review of Efficiency of Plant During Special Investigation.

Although the water supply for Geneva has been of satisfactory quality, the operation of the purification plant has been attended with several difficulties, among which may be mentioned the growths in the reservoir, necessitating its cleaning at regular intervals. While it is probable that by proper treatment with copper sulphate this growth might be temporarily destroyed, no permanent results can be obtained until the organisms have been removed from the river water at the plant. As this is practically impossible, it would suggest the necessity for providing some means whereby the reservoir may be more readily cleaned, which might be accomplished by building a low wall dividing the reservoir into two compartments, each of which should be provided with a separate inlet and outlet. The growth might also be removed by covering the reservoir, which, however, would require considerable expense.

The use of unusually large quantities of wash water has been noted and is due to the small capacity of the coagulating basin and the lack of agitation in the filter. The most economical operation of the plant would require the installation of another basin, so that the total period allowed for coagulation and sedimentation would be about seven hours. With such a basin there would result the necessity for less wash water and coagulant, and also greater ease in operation of the plant particularly during such times as the river is turbid. That the results obtained by the basin have been improved during the special investigation has been due to the use of a better grade of alum.

The water supply for Geneva has always been found potable, clear, soft, containing but little color, and of an excellent quality for domestic and industrial uses.

COST OF INSTALLATION.

The total cost of installing the Geneva waterworks is shown in the following table:

COST OF WATER PURIFICATION PLANT AT GENEVA.

Water rights	$ 6,829
Administration	6,103

Includes advertising, engineering and prospecting.

Intake and repairs on dam		2,871
Conduit	$ 400	
Gates	125	
Intake	500	
Repairs on dam	1,846	
Building		5,032
Includes outside walls and superstructure.		
Foundation for pumps and filters		801
Contract — N. Y. Cont. Jewell Filt. Co.		3,850
Pumping machinery		7,804
Penstock	$ 600	
Power pumps	3,938	
Centrifugal pump	225	
Fittings	450	
Turbine	709	
Shafting	282	
Gas engine	1,600	
Reservoir		7,088
Distributing system		46,304
Pipe	$28,265	
Valves	1,601	
Hydrants	1,771	
Labor	14,667	
Service connections		2,581
Materials	$ 815	
Labor	250	
Meters	1,516	
Total cost of construction		$89,263

COST OF OPERATION OF GENEVA PLANT FOR YEAR 1907.

The following table shows the total expense incurred by the operation of the Geneva plant for the year 1907. It will be seen that the salary of a superintendent, at $50.00 per month, is included and it should be stated that only a portion of his time is paid for at this rate. The low cost for pumping, $222.25, results from the use of water power as it has been necessary to run the gasoline engine but 21 days during the year. The cost of installation includes the purchase of a water right at $6,829, the interest on which should be included in the cost of operation for purpose of comparison. The table also includes the expense of maintaining the distribution system for which one man is retained at $40.00 per month:

Superintendent — $50. per mo.	$ 600.00
Board of Public Affairs — $50. each	150.00
1 engineer — $70. per mo.	840.00
Coagulant	425.00
Gasoline — 13½ cts. per gal.	222.25
(For pumping 21 days of 22 hrs. each)	
Labor for maintenance of system	480.00
Total cost for year	$2,717.25

Total number of gallons pumped.....91,250,000
Average total cost per million gallons, not including interest on bonds $30.00

TABLE NO. 16.

Geneva — Results of Analyses During Examniations.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	
	1906	A. M.								
104	6-22	11:30	Raw water					50		
107	6-23	9:30	Raw water	4,300			16	135	67	
110	6-23	11:30	Raw water	4,800			22			
		P. M.								
112	6-23	1:30	Raw water				16	86	78	
		A. M.								
108	6-23	10:00	Effluent of filter	40			0	5±		
109	6-22	11:00	Effluent of filter	60			0	0	42	
		P. M.								
111	6-23	12:30	Effluent of filter	90			0	0	52	
113	6-23	4:00	Effluent of filter	400			0	0		
		A. M.								
103	6-22	8:30	Reservoir	110	0	0	6	5±		
		P. M.								
115	6-25	2:00	Reservoir	18	0	0				
		A. M.								
120	6-27	11:00	Reservoir	35	0	0				
101	6-22	8:30	Res. D. D. Haines	400			8	5±		
102	6-22	8:30	Res. C. J. Chamberlin	220			8	5±		
		P. M.								
116	6-25	3:45	Res. C. J. Chamberlin	130	0	0				
117	6-25	4:00	Res. D. D. Haines	250	0	0				
		A. M.								
118	6-27	11:30	Res. C. J. Chamberlin	150	0	0				
119	6-27	11:30	Tuttle House	200	0	0				
512	9-15	8:15	Raw water	330			130[1]	40	41	
517	9-15	10:15	Raw water				130[1]	35	41	
		P. M.								
521	9-15	1:05	Raw water	430					41	
523	9-15	2:45	Raw water	300	0	0		30	41	
		A. M.								
513	9-15	8:45	Set. water on filter	150						
		P. M.								
522	9-15	2:00	Set. water on filter	225						
		A. M.								
511	9-15	7:50	Effluent of filter				20	<5	15	
516	9-15	10:15	Effluent of filter				35	<5	18	
519	9-15	11:15	Effluent of filter	35			35	<5	23+	
		P. M.								
520	9-15	1:00	Effluent of filter	46			35	<5	23	
524	9-15	2:45	Effluent of filter		0	0	50	5±	23	
		A. M.								
509	9-15	6:30	Res. C. J. Chamberlin				20	<5	12	
510	9-15	7:00	Reservoir				20	<5	12	
		P. M.								
525	9-15	4:15	Reservoir		0	0	20	<5	12	

[1] Color determinations on unfiltered samples of raw water.

TABLE NO. 16 — Continued.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	CO_2
	1907	M.								
958	1-31	12:00	Raw water	130,000	0	0	50	30±	36	5.0
		P. M.								
961	1-31	2:00	Raw water	115,000	0	0	35	30±	36	3.0
		A. M.								
966	2-1	8:30	Raw water	39,000	0	0	35	30±	36	3.0
		P. M.								
969	2-1	2:00	Raw water	5,000	0	0	35	30±	32	3.0
959	1-31	12:30	Set. water on filter	43,000	0	0	15	.....	16	.....
962	1-31	3:00	Set. water on filter	90,000	0	0	8	.....	18	.....
		A. M.								
967	2-1	8:30	Set. water on filter	25,000	0	0	10	.....	16	20
		P. M.								
960	1-31	1:15	Filter effluent	13,500	0	0	5	5±	17	15
963	1-31	3:39	Filter effluent	26,000	0	0	6	5±	17	.....
		A. M.								
965	2-1	8:30	Filter effluent	6,000	0	0	8	5+	16	16
957	1-31	10:00	Clear well	6,000	0	0	6	5±	20	.....
968	2-1	10:30	Clear well	4,000	0	0	8	10±	16	.....
		P. M.								
970	2-1	3:00	Clear well	900	0	0	8	5±	20	.....
		A. M.								
964	2-1	7:00	Tap at Tuttle House	55	0	0	.....	5±	7	15
		A. M.								
1555	8-9	9:00	Raw water	1,500	0	0	50	25	65	1.0
		P. M.								
1559	8-9	1:30	Raw water	1,100	0	0	50	25	68	.....
		A. M.								
1556	8-9	9:30	Set. water on filter	225	.....	.....	.....	25	41	21
		P. M.								
1560	8-9	1:30	Set. water on filter	275	.....	.....	.....	20	38	22
1564	8-9	5:30	Set. water on filter	260	.....	.....	.....	45	33	.....
		A. M.								
1557	8-9	9:30	Filter effluent	200	0	0	17	<5	38	20
1558	8-9	11:30	Filter effluent	90	0	0	25	<5	41	22
		P. M.								
1561	8-9	1:30	Filter effluent	100	0	0	10	<5	38	19
1563	8-9	3:30	Filter effluent	55	0	0	15	<5	33	23
1565	8-9	5:30	Filter effluent	90	.....	.....	15	10±	32	.....
		A. M.								
1554	8-9	8:30	Reservoir	80	0	0	15	5—	19	4.5
		P. M.								
1562	8-9	3:30	Tap in force main	65	0	0	12	<5	37	.....
		A. M.								
1567	8-10	8:00	Raw water	700	0	0	40	30	56	.....
		P. M.								
1571	8-10	12:30	Raw water	775	0	0	45	.....	51	.....
		A. M.								
1568	8-10	8:30	Set. water on filter	350	.....	.....	.....	35	30	.....
		P. M.								
1572	8-10	12:30	Set. water on filter	160	.....	.....	.....	45	33	.....

Incrustants, Sample No. 969, 30; sample No. 964, 62.

TABLE NO. 16 — Concluded.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	
		A. M.								
1569	8-10	8:30	Filter effluent.....	80	0	0	15	5—	28	.....
1570	8-10	10:30	Filter effluent	15	0	0	20	<5	28	.....
1573	8-10	12:30	Filter effluent	90	0	0	18	15±	28	.....
1566	8-10	7:00	Tap at Tuttle House.....	175	+	+	15	15±	19	.....
1570	8-10	8:30	Tap in force main.....	22	0	0	20	5—	28	.....
		P. M.								
1574	8-10	12:30	Tap in force main.....	60	0	0	15	5—	28	.....

Incrustants, Samp. No. 1559, 21; samp. No. 1554, 45; samp. No. 1566, 50; samp. No. 1574, 47.

LINWOOD PARK.

Linwood Park is one of the numerous small summer resorts on Lake Erie, and occupies a 64-acre tract of land on the high ground bordering Lake Erie just east of the mouth of the Vermillion River. It contains a hotel and about 70 cottages, and is used as a public picnic grounds and for the holding of camp meetings. In the winter but one of the cottages is occupied, while in the summer there is an average population of about 900.

HISTORICAL.

The waterworks were first installed by the Linwood Park Company in 1897, and the supply was obtained from well points driven under the bottom of the lake. These were frequently uncovered by the action of the waves, and at such times unfiltered lake water was pumped direct.

An inspection of the conditions at Linwood Park was made by the engineer of the State Board of Health on July 15th, 1902. In his report it was shown that there was a dangerous pollution of the lake water near the intake of the pumping station, caused by the overflow from cess-pools on the shore of the lake. There were three such cess-pools, the nearest of which was but 180 feet from the waterworks intake.

Not only was there a serious pollution near the intake of the waterworks, but at times the lake water contained considerable suspended matter, so that it was not satisfactory for domestic uses without purification.

In 1906 the sanitary conditions at Linwood Park were much improved. The sewage is collected in one system and discharged into the lake at about 100 feet from the shore line, and approximately 1,000 feet east of the pumping station. This point is sufficiently removed from the waterworks so that there results no pollution at the intake except when the current in the lake is from an easterly direction.

DESCRIPTION OF PLANT.

The waterworks at Linwood Park as inspected in July, 1902, and again during the special investigation by the State Board of Health on August 12th, 1907, comprise a wooden crib near the shore of the lake, two pumps, two storage tanks, and

a distributing system. From the fact that the distributing pipes are laid near the surface of the ground and the water is objectionally warm, a cistern is provided from which the water may be lifted by two hand pumps.

The intake is located 15 feet from the water line and consists of a box of oak plant 9 feet wide by 12 feet long in the direction of the shore line. The bottom was carried down to rock, which was found at a depth of about 11 feet below the surface of the sand. Water generally stands in the crib to a depth of 5 feet and at the same level as that in the lake.

Two small direct acting pumps are provided to lift the water to the storage tanks. These tanks are both elevated, with a capacity of about 23,000 gallons, and at such a height that water will flow from them through the entire distributing system.

EXAMINATION OF AUGUST 12TH, 1907.

The waterworks at Linwood Park were examined once during the special investigation by the State Board of Health, on August 12th, 1907. At that time water was pumped to the storage tanks twice during the day and the examination extended during one afternoon's pumping. But three samples were collected, one from the lake about 50 feet from the shore line and opposite the intake, one from a tap at the pump, and one from a tap in the kitchen sink at the hotel. Results of the analyses of these samples are shown in the following table:

SAMPLES FROM LINWOOD PARK.

Time.	Source.	Bact. per c. c.	Parts Per Million. Turb.	Chlorine.	Alk.	Total Hard.
Aug. 12th						
4.30 P. M.	Lake near crib	325	20±	6.5	91	113
4.30	Tap at pump	19	<5	6.5	154	241
4.30	Tap in kitchen at hotel	34	<5	8.2	164	244

Each sample was examined for the presence of coli, but none were found even in 100 c. c portions.

The bacterial counts were obtained from plates poured immediately after the samples were taken. The containers were then iced and shipped to the laboratory at Columbus to be examined for coli, where through a misunderstanding they were also plated and the following counts obtained:

Source.	Bacteria per c. c.
Lake near crib	720
Tap at pump	9300
Tap in kitchen at hotel	7200

The above results show the unreliability of bacterial counts obtained in this manner, even on samples that are well iced during transportation.

The evidence obtained at this examination show that the water supply at Linwood Park is obtained not from the lake but from ground sources, as the lake

water contained 113 parts per million total hardness, while the supply contained 242 parts per million. It was the opinion of the engineer that practically all of the water pumped had filtered into the gallery on the lake side, but the above determinations show that this is not so. Although the water was somewhat hard it was potable, as shown by the absence of coli and the low bacterial content, and was evidently of very satisfactory quality for domestic use. That its source is from the ground and not from the lake is of advantage in that there is less liability for its pollution during easterly winds at which times the currents in the lake carry the sewage of the park toward the intake.

LORAIN.

The city of Lorain is in the northern part of Ohio in Lorain County on Lake Erie at the mouth of the Black River. Its population in 1906 was estimated at 30,000. In recent years the city has experienced a very rapid growth, and it has been impossible for public improvements to keep pace with it. Its industries consist of a large steel plant, a ship yard, railroad shop, ore and coal handling, and a large amount of general manufacturing. There is a large foreign element in its population from the steel works and docks.

HISTORICAL.

The water supply was first taken from Lake Erie direct without purification, but as it subsequently proved unwholesome, a purification plant was installed by which the lake water was filtered through a battery of mechanical filters of the old wooden tub type. This was one of the first plants in the United States in which mechanical filters were used to purify a municipal water supply. As the water consumption at Lorain increased very rapidly the capacity of the filter plant was soon exceeded and it was replaced by a modern filter plant containing many of the most recent devices that have been developed.

In the following report it is intended to show the causes that made necessary the purification of the Lorain water supply, and to follow this first with a description of the old purification plant, its operation and the results obtained and to conclude with a similar statement with reference to the new purification plant.

Original Installation.

The waterworks were first installed by the city of Lorain in 1884. The supply was taken from a crib in Lake Erie about 1,440 feet from the shore line and 2,000 feet west of the mouth of the Black River. The plant comprised an intake, pumping station and distributing system. The Holly system of pumping direct was used, and no storage of water other than that in the mains was provided. This supply was satisfactory until 1892, when a system of sanitary sewers was constructed in Lorain and these carried practically all of the sewage of the city into the Black River. The effect of this sewage on the wholesomeness of the supply is indicated by the fact that the typhoid death rate for 1893 increased to the unusually high figure of 183 per 100,000.

Conditions Leading to Purification.

Although Lake Erie receives a large quantity of pollution, owing to its large watershed there is a very great dilution, such that the normal water in the lake,

although occasionally turbid, contains no evidence of pollution. During west winds, the water at the intake of the Lorain plant consists of normal lake water, but during easterly winds the currents in the lake are reversed and under such conditions the waters of the Black River are carried directly over the intake and the supply is then badly polluted. The Black River receives not only the greater part of the sewage from Lorain itself, but also the wastes from the city of Oberlin, 20 miles above Lorain, and from Elyria, which is but seven miles above the mouth of the river.

Not only was the death rate from typhoid fever excessive in 1893, but it continued to be high, and it was for the removal of this disease that the water purification plant was built in 1897. Although plans of the plant were not submitted to the State Board of Health for approval, the Board was assured of its efficiency by a five weeks examination of the plant made by Allen Hazen, C. E. of New York, at their expense. From the facts then determined, the plant was approved on condition that the maximum rate of filtration be limited to 100 million gallons per acre per day, and that 2.5 grains of alum per gallon be used.

The use of this plant was continued until the spring of 1907, and the results obtained during the several years operation are discussed under the summary of the results of the special investigation of the State Board of Health.

DESCRIPTION OF FIRST PURIFICATION PLANT.

The old purification plant comprises six gravity mechanical filters with coagulating compartments beneath, tanks for the preparation and storage of coagulant solutions and necessary appurtenances, and a clear well. These are all housed in a substantial brick building immediately south of the pumping station.

INTAKE.

The supply is taken from the old intake provided with the original installation, and from a second intake added in 1905. The former consists of a wooden crib 1,440 feet from the shore line and 2,000 feet west of the west breakwater, from which crib a 12-inch cast iron pipe extends to a forebay on the lake shore. The new intake is also a wooden crib 1,700 feet from the shore and about the same distance from the west breakwater, and a 24-inch cast iron pipe extends from this crib to the same forebay. The lake is about 24 feet deep at both cribs, and water is taken into the old 12-inch pipe 6 feet from the bottom and into the 24-inch pipe 8 feet from the bottom of the lake.

PUMPS.

Into the forebay, which is 13 feet in diameter by 18 feet deep, extend the suctions of the low service pumps, which comprise one horizontal duplex Gordon pump of 2 million gallons capacity installed in 1896, and a Holly crank and fly wheel pump of 5 million gallons capacity on low service installed in 1898.

In 1898, a Holly crank and fly wheel pump with a capacity of 3 million gallons per day was added for high service, which pump forces the water from the clear well directly into the mains at an average pressure of 80 pounds per square inch.

COAGULANTS.

The coagulants used are copperas and lime, the former obtained from the American Steel & Wire Company, while the latter is a Marion lime, obtained from a local dealer in Lorain. The copperas is shipped in bags containing 200 pounds each, while the lime is shipped in barrels containing 190 pounds.

Means for Applying Coagulants.

The coagulant plant is contained in a separate building adjoining the filter house, and comprises a dissolving and a slaking tank, four large storage tanks and three solution pumps. The slaking and dissolving tanks are of wood and each hold about 300 gallons, while the storage tanks are also of wood, 13'-8" in diameter by 7' deep with an available capacity of 7,000 gallons each. The tanks are arranged in tiers with the slaking and dissolving tanks above. Each of the latter discharge into one of the storage tanks and thence into another storage tank, the top of which is on a level with the bottom of the first storage tank. From the last tank the solutions are lifted by duplex steam pumps and forced into the raw water main leading to the filters. The discharge from the iron pump enters the main near the raw water pump and the discharge from the lime pump enters the main about 40 feet beyond the point of application of the iron. All of the solution piping is of 2-inch wrought iron.

Coagulating Basins.

The only provision for the coagulation of the water and its sedimentation before filtration is in the compartments below the filter tanks. These are shown in the detail drawings on Plate No. XI, and have a total capacity of approximately 60,000 gallons, which, at 2,200 gallons per minute, gives a total coagulating period of less than 30 minutes. The lack of better coagulating facilities has been the cause of considerable difficulty in operating the plant.

Filters.*

The filter plant comprises six Jewell filters, each 17 feet in diameter with a total area of 1,362 square feet, or .0312 acre. The guaranteed capacity of the plant is 3 million gallons per day, corresponding to a net rate of approximately 100 million gallons per acre per day. The strainer system is composed of 896 perforated brass strainers, which are screwed at 6-inch intervals into 1¼-inch wrought iron pipes 6 inches apart.

The filtering material consists of 4 feet of round grained sand, obtained from Red Wing, Minn. As originally installed its effective size was 0.52 m. m. and its uniformity coefficient 1.3, but in the latter part of 1906, owing to accumulations of lime on the grains, the sand had an effective size of 0.61 m. m. and a uniformity coefficient of 1.3. Although the sand originally contained no material soluble in hydrochloric acid, in the latter part of 1906, 39 per cent. of its weight was soluble.

The wash water is applied by a connection to the force main and its rate of application is controlled by a valve in the connection to the main. Washing is assisted by mechanical agitators in the form of iron rakes extending about 2 feet into the sand.

No automatic rate controllers are provided on the effluent from the filters, nor loss of head gages to indicate when the filters are dirty.

Clear Well.

As in the original installation, there is no storage provided beyond the high service pumps, except in the mains. In order to equalize the output of the filter plant, and also to provide storage in case of fire, a clear well is provided beneath the filter house. Although the clear well has a total capacity of 225,000 gallons, and its total depth is about 11 feet, for fire protection it has been found necessary to maintain at least 5 feet of water in the clear well at all times, so that the maximum storage of filtered water available has not been more than 100,000

*See Plate XI.

gallons, a quantity, which at the average rate of pumping, 2,200 gallons per minute, gives a working storage capacity of 45 minutes.

EXAMINATIONS.

During the special investigation by the State Board of Health, the old water purification plant at Lorain has been visited four times; on May 25th, August (20-21), October (17-22) and December 13th, 1906. Regular examinations were made except on the first and last visits, when the plant was inspected.

During the examination of October (17-22) special attention was paid to determining the rates of filtration and the actual quantity of water pumped on both high and low service.

OPERATION.

When the water purification plant is in operation, water flows by gravity through the intake into the forebay, from which it is pumped into the coagulating compartments beneath the filter tanks, receiving the coagulant on the way. The coagulated water is forced upward through the coagulating tanks and into the filters, through which it flows by gravity into the clear well. From the clear well it is forced by the high service pumps into the distributing system.

During the first part of 1906, the chemist employed at the filter house was in responsible charge of the plant, while the superintendent of waterworks was in charge of the pumping station and distributing system. In November, 1906, the superintendent of waterworks was placed in immediate charge of the filtration plant also.

The operation of the purification plant is distinct from that of the pump house and is performed by three filter attendants who are under the immediate charge of the chemist employed to superintend the operation of the plant, and also to make the necessary daily analyses. In the absence of a distribution reservoir it is necessary to run the filters continuously, and the operation of the plant is divided into three periods of 8 hours each.

Complete records of the quantity of water pumped, coagulants applied, and such chemical and bacterial data as are obtained have been kept at Lorain for several years, and copies of some of these records are shown in Table No. 23. In the first column, "Average Daily Consumption," the figures shown have been obtained by correcting the average daily consumption on the chemist's records and the correction applied is proportioned to the ratio between the quantity pumped as shown on his records, and that actually pumped into the mains, as indicated in the superintendent's yearly report.

Average Daily Consumption.

In Table No. 17 is shown the average daily consumption as computed from the superintendent's yearly reports, and there are included also the corresponding populations, gallons per capita and the yearly increase in average daily consumption. The figures showing the average daily consumption are of interest as they indicate that the capacity of the new plant will be exceeded in less than seven years unless there is a decided change in the present yearly increase in consumption. The figures indicate also that the guaranteed capacity of the old filter plant has been exceeded since 1904.

TABLE NO. 17.

Average Daily Consumption.

(Gallons.)

Year Ending.	Average Daily Consumption.	Population. (Est.)	Gallons Per Capita.	Increase in Average Daily Consumption.
Mar. 19, 1901	2,241,000	18,700	120	.....
Mar. 19, 1902	2,284,000	21,000	109	43,000
Dec. 51, 1903	2,416,000	23,500	103	132,000
Dec. 31, 1904	2,889,000	25,000	116	473,000
Dec. 31, 1905	3,124,000	27,600	117	235,000
Dec. 31, 1906	3,187,000	30,000	106	63,000
Dec. 31, 1907	3,910,000	32,000	122	723,000

METHODS OF APPLYING COAGULANTS.

The methods of applying the coagulant have been practically the same throughout the investigation. In preparing the lime solutions, 75 pounds of lime are placed in the slaking tank, water added, and the mixture then thoroughly stirred for about 15 minutes. The resulting strong milk of lime is run into the first storage tank where it is diluted to 7,000 gallons. The theoretical strength of the lime solution is 75 grains per gallon. No agitation is provided in the storage tanks, and analyses have shown that its strength maintains about 60 grains per gallon, the strength of a concentrated lime water.

The solution remains in the first storage tank until required when it is run out into the second and lower tank also containing no agitators, and from which it is lifted by the solution pump and forced into the raw water mains. The rate of application of the solution depends on the speed of the solution pump.

The method of preparing the copperas solutions is similar to that in use for the lime and a charge of 400 pounds of copperas is dissolved and run through into the first storage tank where it is diluted to 7,000 gallons, so that the resulting solution has a theoretical strength of 400 grains per gallon.

One of the three pumps is generally used for applying the copperas solution and one for the lime solution, while the third pump is maintained in reserve and can be used to handle either coagulant. Considerable trouble has been experienced in keeping these pumps in repair, a fact which has materially increased the difficulties in securing proper treatment.

QUANTITY OF COAGULANT APPLIED.

The method in use for coagulating the water is to apply such a quantity of copperas as is deemed necessary and to so adjust the quantity of lime as to give a slight red color in the filtered water when tested with phenolphthalein. In Table No. 18 is shown the average quantity of coagulants that it has been found necessary to apply at Lorain for the years 1900, 1904-6. These figures have been obtained from the superintendent's annual reports. In the year 1900 the coagulant in use was aluminum sulphate, and the average quantity was 1.74 grains per gallon. The average quantity of copperas used for the last three years was 2.43 grains per gallon, during which time also 0.96 grain of lime was applied.

TABLE NO. 18.

Average Quantities of Coagulants Applied.

Year.	Daily Consumption.	Copperas Used.		Lime Used.		Alum.
		Pounds.	Gr. per Gal.	Pounds.	Gr. per Gal.	Gr. per Gal.
1900	2,241,000	.....	.....	.....	.....	1.74
Jewell Iron Process from Feb. 8, 1901 to July 12, 1903.						
1904	2,889,000	323,497[1]	2.18[2]	115,487	0.77	.....
1905	3,124,000	401,447	2.46	176,189	1.08	.....
1906	3,187,000	436,598	2.62	169,680	1.02	.....
Average	.....	.....	2.43	.....	0.96	.....

[1] Used also 5,843 pounds of alum.
[2] Includes alum used.

The maximum quantity of copperas and lime used on any one day during the last four years, and the corresponding turbidity of the lake water are shown in Table No. 19. These results are of interest as indicating an occasional very turbid water in Lake Erie, a water which requires unusually large quantities of coagulant.

TABLE NO. 19.

Maximum Quantity of Coagulant Used.

Year.	Date.	Turb. of Lake Water.	Maximum Quantity of Coagulant Used. Gr. per Gal.		
			Copperas.	Lime.	Alum.
1903	September 11	Not Given	.....	.....	3.00
1904	January 24	Not Given	4.02	1.00	.....
1905	April 17	350	4.02	1.66	.....
1906	December 7	800	4.17	1.33	.....

COAGULATING BASINS.

Although the results accomplished by the coagulating basins are of great importance in determining the efficiency and ease of operation of the plant, the actual operation of the basins requires no particular attention except from occasional cleaning. It is found necessary to flush them out about twice a month, at which times from one to two feet of deposit is removed.

FILTERS.

Rate of Filtration. As previously stated, no automatic rate controllers are provided for the filters, and it is the custom to operate them at very different rates. On account of the small storage provided in the clear well, the average rate of fil-

tration is determined by the rate at which filtered water is pumped into the mains. As each filter is washed at least twice in 24 hours, the average time of operating a filter is 23½ hours. The average rate of filtration has been determined by assuming all of the filters in service for 23½ hours, and the quantity filtered as indicated in Table No. 17, showing the average daily consumption. The average rate of filtration in 1900 as computed in the above manner was 73 million gallons per acre per day, and in 1906, 104 million gallons per acre per day. The maximum average consumption, which generally occurs for about 6 hours a day, is at least 25 per cent. greater than the average daily consumption, so that the maximum average rate of filtration during 1906 was approximately 130 million gallons per acre per day.

From the fact that it is frequently necessary on account of lack of water in the clear well to run the filters longer between washings than is desirable, the rate of filtration of such filters decreases rapidly, so that it is necessary to operate the clean filters at very fast rates. This fact was indicated by the numerous measurements of the rates during the different examinations. On August (20-21), 1906, the maximum average rate as measured was 139 million gallons per acre per day, and the minimum average rate 110 million gallons per acre per day. The maximum individual rate was 199 and the minimum individual rate but 56 million gallons per acre per day.

On October 18th, 1906, the actual quantity filtered by the plant from 8:00 A. M. to 9:00 P. M. was obtained by numerous measurements of the rate of filtration, and was found to be at the rate of 3,720,000 gallons in 24 hours. This corresponds to an average rate of 119 million gallons per acre per day. The maximum individual rate was 201, and the minimum individual rate 87 million gallons per acre per day.

The above figures are of interest as indicating the extreme range in the rates at which the filters are operated. In general it may be said that these great variations are caused both from the fact that the capacity of the plant is largely exceeded and also from the fact that there is not a sufficient storage of filtered water in the clear well.

On October 18th, 1906, not only was the quantity of water filtered measured, but the quantity pumped into the mains was determined by reading the counters on the pumps. The corrected difference of these two figures indicate that the high service pump had a slippage of 8.5 per cent., a figure which closely agrees with the slip allowed in the superintendent's annual report.

Washing. No loss of head gages are provided to indicate when the filters are dirty, and it is the custom to wash them at stated times, generally two filters every four hours. Washing is sometimes delayed longer on account of lack of storage in the clear well.

From the fact that the wash water is obtained by a connection to the force main, its rate of application varies with the degree of opening of the regulating valve, and also with the pressure in the mains. As large volumes of water are used during washing, the pressure in the mains occasionally drops during the operation so that the actual rate of application of the wash water is sometimes less toward the end of the operation.

It is the custom to keep open the valve that supplies the coagulated water to the filter, so that both coagulated and filtered water are applied during the operation of washing. The actual rate of application of the wash water as determined by frequent measurements during the different examinations, was found to be 12.9 inches per minute vertical rise on an 18-foot circle. When the coagulated water is shut off the rate of rise is 10.4 inches per minute. The average time of washing is about 9 minutes, and the total quantity of water per wash corresponds to a total

rise of 9.7 feet or 16,400 gallons, including approximately 3,200 gallons of coagulated water.

As two filters are generally washed every four hours, the total number of washes per day is 12, and the total quantity of wash water used 196,000 gallons, including 38,000 gallons of coagulated water. This is 6.2 per cent. of the total quantity of water filtered.

CHARACTER OF RAW WATER.

The general characteristics of the raw water at Lorain are well indicated in the daily records for the years 1905-6 (Table No. 23), and the evidence contained in these records, together with that obtained during the examinations of both the old and the new plants will be considered in discussing the character of the raw water.

General Character of Lake Water.

The average turbidity during 1905-6 was 70 parts per million. This was greatly exceeded at times, and occasionally for long periods, and it is apparent that during the winter months the lake is much more turbid than during the summer. The average turbidity during December, 1905, and 1906, was 150 parts per million. The color determinations shown in the daily records have little value, as they were read on unfiltered samples. The evidence obtained during the examinations indicates, however, that Lake Erie water has an average dissolved color of from 10 to 15 parts per million. The temporary hardness of the lake water remains very nearly constant except when effected by local conditions, and is about 90 parts per million.

The bacterial results in the daily records indicate that the normal bacterial content of the lake water is about 3,000 per c. c., although it is frequently very much greater as is indicated by the records for February and March, 1905. During the summer months when the lake is comparatively quiet, the average bacterial content is about 1,000 per c. c. The evidence obtained during the examinations indicates that the lake water normally contains very little if any pollution, as is indicated by the absence of coli even in 100 c. c. portions.

It is apparent from the above discussion that under normal conditions the purification of Lake Erie water at Lorain requires merely the removal of objectionable suspended matters to produce a very satisfactory water for domestic use. During such times as easterly winds prevail, however, the character of the raw water is very greatly changed, as was well shown during the examination of June (3-8), 1907.

Lake Water During Examination of June (3-8), 1907.

At the beginning of the examination of June, 1907, the wind blew strongly from the northeast until early in the morning of June 6th, when it changed and blew very strongly from the northwest. The effect of the river water on that in the lake at the intake is very well indicated by the high chlorine and color and by the decrease in temporary hardness. The bacterial results are of special interest and indicate a very decided increase in the total number contained, while the examinations for coli, using bile media, indicate that at least two were present in each c c. of the raw water. That the conditions were improving during the examination is indicated by the decrease in bacterial content and dissolved color, and also by the slight decrease in chlorine.

The effect of the northwest wind on June 6th is indicated by the gradual changing to normal lake water, although the evidence indicates that on this day there was still a considerable pollution of the water at the intake. There was

a decrease in the number of coli, as they were present in but 50 per cent. of the .5 c. c. portions of raw water examined.

The results obtained in the above examination are of great interest, as they indicate to what a large extent the lake water is occasionally polluted by the Black River. During the last year the conditions have been worse than ever before from the fact that a new breakwater has been constructed at the mouth of the river, which breakwater tends to deflect the course of the river directly over the intake when the currents in the lake are from the east.

EFFICIENCIES.

GUARANTEE.

The old purification plant at Lorain is one of the first to be installed under a guarantee covering the efficiencies obtained by the plant. The proposal covering the construction of the filters contains the following statement: "We guarantee said filter plant when operated in accordance with our usual instructions shall have a capacity of purifying an average daily amount of 3 million gallons of water taken from your intake in Lake Erie, so that the same shall be clear and bright, free from suspended matter and suitable for domestic use. We further guarantee that the filters shall make an average reduction of not less than 97 per cent. of the bacteria in the unfiltered water. (It is understood that our guarantee is being fulfilled satisfactorily whenever the number of bacteria in 1 c. c. of the filtrate does not exceed the recognized limit of safety which is 200 bacteria per c c.)."

INTAKE.

Although no trouble has been experienced at Lorain in obtaining a sufficient quantity of water through the intake, it is apparent that, particularly since the recent extension of the west breakwater, the location of the intake is such as to cause a very serious pollution of the water supply during east winds. This occasional pollution could be largely eliminated by extending the intake a few hundred feet farther north or beyond the sphere of influence of the Black River.

RAW WATER PUMP.

Considerable difficulty has been experienced not only in operating the raw water pump at a constant rate, but also in providing a sufficient quantity of water to keep all of the filters in operation. This was particularly noted on the examination of October, 1906, at which time the sand in the filters was frequently uncovered owing to an insufficient supply of water. From the measurements taken at this time it is apparent that the low service pump had a slippage of very nearly 40 per cent. which was due in part to wear of the cylinders and in part to the fact that several valves in the pump were broken.

APPLICATION OF COAGULANT.

The methods of applying the coagulants were generally satisfactory during the early operation of the plant. Considerable difficulty was experienced in keeping the solution pumps in repair, particularly that one used for applying the iron, as it was corroded by the solutions. The solution pipes, which were of 2-inch wrought iron, gave considerable trouble, and in the fall of 1906 it was found necessary to replace the iron solution pipe which had become nearly closed with a hard yellow scale.

During the latter part of 1906 it was the custom to apply nearly a constant quantity of coagulants and the rate of application during the day was the same as that during the night, although the rate of pumping was considerable less at night. Although it was apparent on the examination of October, 1906, that better efficiencies of bacterial removal would have been obtained using more coagulant, the operator stated that it was impossible to do this as the solution pumps were in such a state of repair that it was impossible to obtain the proper adjustment of coagulants.

Following the examination of December 13th, 1906, at which time the results obtained by the plant were very poor, the Board of Public Service were advised by the State Board of Health to discontinue the use of copperas and lime and to use alum as during the early operation of the plant. Among the reasons for this recommendation were that the solution pumps were in such a state of repair that it was impossible to apply the coagulants in the proper proportions, and that one coagulant would be very much more easily applied than two; moreover, the evidence obtained during the special investigation had indicated that Lake Erie water is more easily coagulated with alum than with lime and iron. This recommendation was not followed and the use of copperas and lime was continued.

An examination of the sand from the filters revealed the fact that the grains were coated with deposits of lime to an extent of 39 per cent. of their weight. The increase in effective size has been previously noted. Such "after deposits" indicate an excessive use of lime, in quantities greater than those necessary to neutralize the copperas applied. Although it had been the custom to maintain but a slight quantity of mono carbonates in the filtered water, occasionally the quantity of lime had been increased and there had resulted in the filtered water from 15 to 30 parts of mono carbonates, which tended to deposit in the filters. This trouble had been guarded against during 1905 by the occasional use of less quantities of lime, resulting in a slightly acid water which tended to dissolve out the deposits. It is of interest to note the occurrence of similar deposits at Marietta. The evidence indicates that the use of copperas and lime as coagulants requires a very accurate adjustment of the two, as an excess of lime causes "after deposits" in the filter, while the use of too small a quantity of lime causes a very poor coagulation.

These facts are of interest in considering the report of a test of the Lorain plant during the week beginning November 12th, 1906, made by Mr. C. Arthur Brown of The American Steel & Wire Company at the request of the board of public service to investigate the condition of the filter plant. In his report is the following:

"The first point to receive attention was the chemical character of the lake and filtered water. An examination of these proved up a serious error in the use of the coagulant. It led to an investigation of the condition of the filter beds and here one of the serious faults was found. It is necessary in the use of the coagulant to use enough caustic lime to absorb all of the free carbonic acid in the raw water and a portion of the semi-combined carbonic acid as well. To put the matter in a plainer way it is obligatory to use enough of the caustic lime to slightly soften the water. If this is not done the sand beds get into what we term an acid condition and in this state they will not properly perform their work, especially if the conditions are as they are in this plant. If, however, the proper amount of lime has been used, the filter beds do not get in this condition and consequently when they are called on to do a little additional work they have a reserve to draw on, somewhat as a man in good health stores up a certain amount of energy and reserve which may be called upon in time of sickness or unusual demand. At this time the water was requiring a free use

of lime to get the best results and the condition of the chemical pumps was such that the proper amount of lime could not be added to obtain the best results. The conditions in the beds made a still larger use of lime of importance. An old pump was placed on the platform over the chemical tanks and used to stir up the lime solution and in this way strengthen the solution of lime so more of it could be brought into use. * * * With the pump now in place the strength of the lime solution can be increased so as to probably meet any emergency. This will be simplified if particular care is taken to use enough lime at times when the water is not so bad in the lake so that the abnormally large amounts used on the first four days of the investigation will not be necessary."

It would seem from the above report that Mr. Brown recommended the use of lime in such quantities as would tend to form "after deposits" in the sand. The wisdom of such a procedure is not apparent as these "after deposits" have practically doubled the size of the sand in the filters and have also increased the difficulty of properly washing the filters. It was on Mr. Brown's recommendation, also, that when the new plant was started in operation an excess of lime above that required to neutralize the copperas was used, and similar trouble from "after deposits" was experienced in the new plant, this time in the air pipes.

In general it should be stated that such accumulations in the filters represent one of the most serious difficulties in the use of copperas and lime as coagulants, and this fact was apparently not appreciated by those advocating their use.

Coagulating Tanks.

The small capacity of the coagulating tanks has probably had a greater effect in determining the poor results obtained by the Lorain plant than any other one feature. Not only is there little removal of bacteria and suspended matters accomplished, but there is not a sufficient time allowed for the completion of the chemical reactions, particularly with the lime.

Filters.

The bacterial removals obtained by the plant are perhaps best indicated in the daily records in Table No. 23. These records indicate a satisfactory operation of the filters for 1905, and a gradual falling off in their efficiency during 1906. In December, 1906, the bacterial removal obtained was but 88 per cent. It is probable that the removals obtained by the filters during 1906 were largely influenced by the accumulations on the sand grains, which accumulations were eliminated during 1905 by a skilful manipulation of the coagulants. The quantities of coagulants applied during the latter part of 1906 were considerably above the average, which would indicate that this feature had little effect on the results. The fact that the capacity of the filter plant was exceeded, causing unusually high rates of filtration, was stated to be the cause of the poor results obtained.

The results of the bacterial examinations of the filtered water obtained during the special investigation by the State Board of Health, indicate a generally satisfactory treatment except when the raw water was contaminated by the Black River. The evidence obtained during the examination of December 13th, 1906, indicates a very poor bacterial removal by the plant and also considerable pollution of the raw water.

The number of postitive presumptive tests for coli in the filtered water as shown on the daily records in Table No. 23, are of considerable interest and they indicate a less wholesome water during the latter part of 1906 than at any other time.

SUMMARY OF INVESTIGATION OF OLD PLANT.

The results that have been obtained by the old purification plant from the time of its installation until it was abandoned in the spring of 1907 have been greatly influenced by the use of different methods of coagulation. Although alum proved very satisfactory for several years, it was expensive, and in the hope of reducing the operating expenses of the plant, its use was discontinued and the water was subsequently coagulated using first the Jewell Iron Process and later copperas and lime. In the following discussion is shown the efficiency of the results obtained during the several treatments as has been indicated by the typhoid death rate, shown in Table No. 20. While it has been impossible to obtain a satisfactory record of the typhoid cases in Lorain, the deaths are carefully reported and the figures in Table No. 20 have been obtained from the records of the health officer. Although no investigation of the causes of infection has been made, that there is a relation between the prevalence of typhoid fever and the wholesomeness of the water supply is indicated by the fact that the cases are distributed over the entire city.

Efficiencies of Plant Previous to Special Investigation.

From its installation until 1901, the filtration plant was operated using alum as a coagulant and the results indicate that a very satisfactory water was obtained with an average amount of 1.7 grains per gallon. The wholesomeness of the supply is shown by the very small death rate from typhoid fever during this time. In 1900, the developments in the art of treating waters indicated that more economical results could be obtained with other coagulants, and, although the results obtained with alum were very satisfactory, in order to reduce the cost of purification the use of alum was discontinued and the Jewell Iron process was installed in 1901. This method of coagulation was used from February 8th, 1901, until July 12th, 1903, and that the water supply was wholesome during this time is indicated by the fact that there were no deaths from typhoid fever in 1901 and but four in 1902. In July, 1903, however, it was found that the bottoms of the filters had rotted away, and although the necessary repairs could have been made on the different filters in succession, the entire plant was immediately put out of service. From July 12th to September 11th, 1903, unfiltered lake water was pumped and that the water supply was then unwholesome is indicated by the 12 deaths from typhoid fever during the last five months of 1903.

When the repairs were completed the filter plant was again operated for a short time using alum as a coagulant, but on October 15th, 1903, the Lorain authorities requested permission of the State Board of Health to use sulphate of iron and lime as coagulants in place of alum. The Board granted permission to make a test of the use of copperas as a coagulant in place of alum for a sufficient length of time to determine its efficiency, and as a subsequent test indicated satisfactory results, the use of copperas and lime was continued.

The probable unwholesomeness of the water supply, due to inexperience in the proper use of the new coagulants when first introduced, is indicated by the six deaths from typhoid fever during the first six months of 1904. The continued use of the process resulted in greater skill in its manipulation and a more wholesome supply as is indicated by but one death from typhoid fever in 1905.

TABLE NO. 20.

Typhoid Fever Deaths in Lorain, Ohio.

Years.	Population.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Per 100,000.
1889	4,500	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	1	2	44
1890	4,860	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	1	21
1891	5,200	.....	.....	.....	.....	.....	.....	.....	.....	1	2	.....	.....	3	57
1892	5,600	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	2	.....	3	54
1893	6,000	1	.....	2	6	1	.....	.....	.....	1	.....	.....	.....	11	183
1894	8,200	.....	.....	1	.....	.....	.....	.....	2	.....	1	.....	.....	4	49
1895	11,400	.....	3	1	4	2	.....	.....	1	3	.....	1	.....	15	131
1896	12,000	.....	3	.....	1	2	1	1	.....	.....	2	.....	.....	10	83
1897	12,300	1	.....	1	1	.....	.....	.....	.....	.....	.....	.....	.....	3	25
1898	14,100	.....	.....	1	.....	.....	.....	.....	1	.....	1	.....	.....	3	21
1899	15,000	.....	.....	.....	.....	.....	1	1	.....	1	.....	.....	1	4	25
1900	16,028	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	1	2	12
1901	18,650	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0
1902	21,000	1	.....	.....	.....	.....	.....	.....	2	.....	.....	1	.....	4	19
1903	23,500	.....	.....	.....	.....	.....	.....	.....	2	2	3	3	2	12	51
1904	25,000	.....	1	1	1	2	1	.....	.....	1	.....	1	.....	8	32
1905	27,600	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	1	3
1906	30,000	1	.....	1	.....	.....	.....	.....	1	.....	1	1	1	6	20
1907	32,000	1	.....	5	1	6	3	1	2	.....	.....	1	4	24	75
Total ...		5	7	13	14	13	6	4	13	11	10	10	10	.....	.....

EFFICIENCY OF PLANT DURING SPECIAL INVESTIGATION.

During the early part of 1906, the results obtained at the plant were generally satisfactory, but in the latter part of the year, as previously discussed, the filtered water was occasionally of very poor quality. These poor results were due to difficulties in handling the coagulants, and to the fact that the plant was operated beyond its efficient capacity, a condition which required frequent excessive rates of filtration. Moreover, the period allowed for coagulation and sedimentation preliminary to the application of water to the filters was even less during 1906, as the plant was handling more water, so that it will be seen that there were three principal points affecting the results obtained by the filter plant, as follows:

1 — Insufficient filtering capacity

2 — Poor preparation of the water for the filters.

3 — Inefficient methods of introducing the coagulants.

Any one of the above features would have been sufficient to cause poor efficiencies by the plant, and it is difficult to state just which one had the greatest effect in producing the poor results actually obtained.

There might also be added that the extension of the west breakwater at the mouth of the Black River during 1906 caused a more direct flow of water over the intake, on which account the raw water was subject to greater pollution and more sudden changes in character. This condition can be remedied by extending the intake farther out from the shore of the lake.

COST OF INSTALLATION OF OLD PLANT.

In Table No. 21 is shown the cost of installation of the intake, pump and boiler houses, and old filtration plant. This includes practically the entire cost of installation with the exception of the old 12-inch intake, and the additions to the coagulating house which were provided when the Jewell Iron Process was installed in 1900.

TABLE No. 21.

24-inch intake		$14,145
Material and labor necessary to lay 1,700' at $4. per foot	$ 6,800	
Pipes, fittings and valves, based on present prices, 1,700' at $3.85 per foot	6,545	
Submerging crib	800	
Forebay		600
Boiler house		12,930
Building	$ 4,700	
2 return tubular boilers, 6'x12', at $1,475	2,950	
1 Scotch boiler, 10-6" x 15'-6"	4,800	
1 steam header, 14"x40'	480	
Pump house		53,840
Building, approximately	7,500	
5 million gallon Holly pump with connections	28,000	
3 million gallon Holly pump with connections	12,000	
2 million gallon Gordon duplex compound pump	6,340	
Old filter house complete		8,904
Total cost of installation		$90,419

COST OF MAINTENANCE OF OLD PLANT.

In Table No. 22 are shown the total disbursements by the waterworks department including the cost of maintenance of the pump and filter houses, office and distribution system. The first part of the table comprises a statement of the total cost of operation and maintenance of the entire system and is divided into labor, coagulants, fuel, interest and other expenses, in which are included the costs of maintaining the office and distribution system. The second part of the table shows the same costs per million gallons pumped. These figures are based on the total high service pumpage.

The total cost per million gallons pumped ranges from $33.26 (1904) to $40.77 (1903). The large cost of 1903 is due to high labor, part of which was incurred by the repairs to the filters made necessary by the Jewell Iron Process, and to the high interest charges. As shown in the table, there should also be included under 1901 and 1903 the increased expense incurred both by the installation of the Jewell Iron Process ($6.097) and the cost of repairs to the filters, including material and labor (approximately $6,400), which total $12,500. This process was used from February 9, 1901, to July 12, 1903, and was provided to decrease the cost of coagulants, which, as shown under 1900, was $3.83 per million gallons.

Alum was used at the plant until February 9, 1901, and, although very satisfactory results were obtained, they were not considered economical. In 1900 alum was purchased at $30 per ton, but since 1905 a very satisfactory grade may be obtained for $20 per ton. At $20 per ton the cost of coagulant in 1900 would be $2.55 per million gallons.

The variable costs due to different processes and methods of operation are coagulant and fuel. An increase in quantity of wash water and in general waste at the plant would also increase the cost of fuel per million gallons. The combined cost of coagulant (at $2.55) and fuel (at $2.91) for 1900 is $5.46. This figure is less than that for any other year shown.

The table indicates that the cost of coagulants is a comparatively small part of the total cost of maintenance. The experience at Lorain indicates that the attempts to obtain greater economy of operation by the use of various coagulants have not been successful financially, and also that they have resulted in the furnishing of an unwholesome water as indicated by the occasionally high typhoid death rate.

TABLE NO. 22.

Lorain — Cost of Maintenance of Old Plant.

(Entire Cost of Maintenance of Water Works.)

	1900.	1901.	1903.	1904.	1905.	1906.
AVER. DAILY CONSUMPTION, MILLION GALLONS	2.241	2.284	2.416	2.889	3.124	3.187
TOTAL DISBURSEMENTS	$27,646	$28,506	$35,976	$35,096	$41,647	$43,707
Labor { Pump House	4,232	4,287	4,647	.....	.....	.....
Labor {	.....	.....	.....	8,190	8,314	7,598
Labor { Filter House	1,451	2,326	4,814[2]	.....	.....	.....
Coagulant	3,122[1]	2,456	1,636	1,887[3]	2,461	2,837
Fuel	2,379	2,672	3,621	4,776	4,285	4,610
Interest	11,350	11,350	12,843	12,657	14,122	18,586
Other expenses	5,112	5,415	8,415	7,586	12,465	10,075
TOTAL COST PER. MILLION GALLONS	33.92	34.18	40.77	33.26	36.52	37.56
Labor { Pump House	5.19	5.14	5.27	.....	.....	.....
Labor {	.....	.....	.....	7.76	7.29	6.53
Labor { Filter House	1.77	2.79	5.46[2]	.....	.....	.....
Coagulant	3.83[1]	2.94	1.85	1.78[3]	2.15	2.43
Fuel	2.91	3.21	4.10	4.52	3.76	3.96
Interest	13.93	13.61	14.56	12.00	12.38	15.97
Other expenses	6.27	6.49	9.53	7.19	10.98	8.66

NOTE: Alum used until February 9, 1901. Jewell Iron Process used from February 9, 1901 to July 12, 1903. Cost of installation of process $6,097; cost of repairs to filters (material and labor) $6,400 (approximately).

[1] At $30 per ton for alum.

[2] Includes extra labor for repairs to filters made necessary by Jewell Iron Process; cost of supplies and materials during repairs $4,609, which is not included under disbursements.

[3] At $9 per ton for copperas.

TABLE NO. 23.

Lorain — Record of Operation 1905-06.

Month.	Aver. Daily Consumption.	Coagulants Grains per Gal.		Parts Per Million. Lake Water.				Parts Per Million. Effluent.		Bacteria per C. C.			Coli in one C. C. Per Cent. Positive Tests.	
		Copperas.	Lime.	Turbidity.	Color.[1]	Alkalinity.	Chlorine.	Color.	Alkalinity.	Lake.	Effluent.	Per Cent. Reduction.	Lake.	Effluent.
1905														
January	2,978,000	2.25	1.24	45	45	94	9.1	0	85	3,300	71	97.8	84	0
February	3,258,000	2.08	.92	30	27	96	9.2	0	90	10,900	134	98.7	67	0
March	3,164,000	3.08	1.34	32	40	88	8.4	2	80	38,000	236	99.4	62	0
April	2,888,000	2.63	1.10	60	70	90	12.7	.....	84	4,000	128	96.8	88	8
May	3,519,000	2.17	.97	43	38	90	16.0	.....	81	1,500	50	96.6	72	0
June	3,024,000	2.17	.96	34	35	90	11.3	.....	83	940	31	96.6	100	17
July	3,057,000	2.37	1.00	41	30	91	12.0	.....	84	1,150	32	97.2	96	11
August	3,144,000	2.39	1.10	46	46	92	11.0	.....	83	2,100	43	97.5	96	4
September	3,060,000	2.42	1.03	56	55	94	10.0	.....	83	1,450	19	97.4	92	0
October	3,020,000	2.59	1.18	65	69	96	9.5	.....	83	1,400	32	97.7	88	8
November	3,216,000	2.81	1.07	71	70	97	9.0	.....	86	910	12	98.1	92	0
December	3,302,000	2.84	1.32	108	89	108	12.0	.....	95	3,100	63	97.3	86	10
Average	3,124,000	2.48	1.10	52	51	94	10.8	.....	84	5,740	71	97.5 or 98.8	85	9
1906														
January	2,915,000	2.82	1.17	53	57	95	9.4	.....	85	1,700	33	97.4	50	10
February	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
March	2,920,000	2.41	.84	87	49	93	11.9	4	92	1,700	43	98.3	55	12
April	2,820,000	2.48	.94	72	68	88	13.2	.....	85	560	15	97.9	56	0
May	3,000,000	2.48	.74	83	78	95	11.0	.....	92	300	6	98.3	33	0
June	3,370,000	2.03	.76	73	98	97	8.0	.....	93	410	25	90.8	38	8
July	3,330,000	2.25	.56	51	96	97	8.1	.....	95	1,000	169	83.4	42	0
August	3,330,000	2.35	.78	56	33	92	8.8	.....	88	850	50	94.0	54	11
September	3,470,000	2.22	.85	43	....	94	9.0	.....	90	850	41	91.0	67	8
October	3,520,000	2.41	.86	112	....	93	9.6	.....	87	1,000	100	90.7	80	26
November	3,350,000	3.33	1.88	139	....	88	13.0	.....	74	4,000	340	90.9	71	7
December	3,280,000	2.90	1.47	194	....	82	16.4	.....	72	7,800	1,050	88.2	59	11
Average	3,187,000	2.52	.98	87	68	92	10.7	.....	86	1,889	172	92.6 or 90.9	55	12

[1] Color of unfiltered samples.

TABLE NO. 24.

Lorain — Results of Analyses During Examinations.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Phen. Alk.
	1906	A. M.								
443	8-20	9:00	Raw water	310	.....	.....	0	20±	88	.....
		P. M.								
448	8-20	1:00	Raw water	55	.....	.....	.....	20±	90	0
456	8-20	5:00	Raw water	80	.....	.....	.....	20—	90	0
459	8-20	9:00	Raw water	80	.....	.....	.....	15+	92	0
			Average	131	.....	.....	.....	18	90	.....
		A. M.								
445	8-20	11:30	Settled water	280	.....	.....	.....	.....	.....	.....
		P. M.								
457	8-20	5:00	Settled water	90	.....	.....	.....	.....	.....	1
		A. M.								
444	8-20	9:00	Tap in laboratory	8	.....	.....	0	<5	81	0
		P. M.								
449	8-20	1:00	Tap in laboratory	18	.....	.....	0	<5	85	—2
458	8-20	5:00	Tap in laboratory	38	.....	.....	.....	<5	89	0
460	8-20	9:00	Tap in laboratory	8	.....	.....	.....	<5	87	0
			Average	18	.....	.....	.....	<5	86	0
		A. M.								
437	8-20	8:45	Effluent No. 1	4	.....	.....	.....	.....	.....	.....
438	8-20	8:45	Effluent No. 2	8	.....	.....	.....	.....	.....	.....
439	8-20	8:45	Effluent No. 3	12	.....	.....	.....	.....	.....	.....
440	8-20	8:45	Effluent No. 4	3	.....	.....	.....	.....	.....	.....
441	8-20	8:45	Effluent No. 5	7	.....	.....	.....	.....	.....	.....
442	8-20	8:45	Effluent No. 6	16	.....	.....	.....	.....	.....	.....
		P. M.								
450	8-20	3:30	Effluent No. 1	10	.....	.....	.....	.....	.....	.....
451	8-20	3:30	Effluent No. 2	8	.....	.....	.....	.....	.....	.....
452	8-20	3:30	Effluent No. 3	3	.....	.....	.....	.....	.....	.....
453	8-20	3:30	Effluent No. 4	22	.....	.....	.....	.....	.....	.....
454	8-20	3:30	Effluent No. 5	22	.....	.....	.....	.....	.....	.....
455	8-20	3:30	Effluent No. 6*	310	.....	.....	.....	.....	.....	.....
			Average	85	.....	.....	.....	.....	.....	.....
	1906	A. M.								
461	8-21	1:00	Raw water	270	.....	.....	.....	15±	91	0
463	8-21	5:00	Raw water	40	.....	.....	.....	15±	91	0
465	8-21	9:00	Raw water	55	0	0	.....	15±	91	—1
		P. M.								
468	8-21	1:00	Raw water	130	0	0	.....	15±	90	0
			Average	124	.....	.....	.....	15±	91	0
		A. M.								
466	8-21	9:00	Settled water	100	.....	.....	.....	.....	.....	.....
		P. M.								
469	8-21	1:00	Settled water	82	.....	.....	.....	.....	91	4
		A. M.								
462	8-21	1:00	Tap in laboratory	20	.....	.....	.....	<5	87	0
464	8-21	5:00	Tap in laboratory	24	.....	.....	.....	<5	86	0
467	8-21	9:00	Tap in laboratory	.....	0	0	.....	<5	80	0
		P. M.								
470	8-21	1:00	Tap in laboratory	40	0	0	.....	<5	83	1
			Average	28	.....	.....	.....	<5	84	1

* Needed washing.
Iron, sample No. 468, 0.3; Sample No. 467, 0.2; Sample No. 470, 0.4.
Used 2.2 gr. of copperas per gal. and 0.8 gr. of lime per gallon (Aug.20-1, 1906.)

TABLE NO. 24 — Continued.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Phen. Alk.
471	8-21	8:30	Effluent No. 1	2	.....	.....	.....	.....	.....	.....
472	8-21	8:30	Effluent No. 2	2	.....	.....	.....	.....	.....	.....
473	8-21	8:30	Effluent No. 3	3	.....	.....	.....	.....	.....	.....
474	8-21	8:30	Effluent No. 4	2	.....	.....	.....	.....	.....	.....
475	8-21	8:30	Effluent No. 5	0	.....	.....	.....	.....	.....	.....
476	8-21	8:30	Effluent No. 6	0	.....	.....	.....	.....	.....	.....
			Average	2	.....	.....	.....	.....	.....	.....
		P. M.								
635	10-17	2:00	Raw water[1]	600	.....	.....	0	35	90	0
643	10-17	9:00	Raw water	6,800	.....	.....	.....	60	90	0
			Average	3,700	.....	.....	.....	50	90	0
636	10-17	2:00	Settled water	660	.....	.....	.....	.....	97	11
634	10-17	1:30	Tap in laboratory	105	.....	.....	0	0	82	2
644	10-17	9:00	Clear well	55	.....	.....	.....	<5	87	0
	1906	P. M.								
637	10-17	4:00	Effluent No. 1	85	.....	.....	.....	.....	.....	.....
638	10-17	4:00	Effluent No. 2	26	.....	.....	.....	.....	.....	.....
639	10-17	4:00	Effluent No. 3	75	.....	.....	.....	.....	.....	.....
640	10-17	4:00	Effluent No. 4	55	.....	.....	.....	.....	.....	.....
641	10-17	4:00	Effluent No. 5	65	.....	.....	.....	.....	.....	.....
642	10-17	4:00	Effluent No. 6	80	.....	.....	.....	.....	.....	.....
			Average	64	.....	.....	.....	.....	.....	.....
		A. M.								
645	10-18	5:00	Raw water	2,200	.....	.....	.....	40	90	0
		P. M.								
650	10-18	1:00	Raw water	5,800	.....	.....	.....	40	90	0
653	10-18	8:00	Raw water	14,000	.....	.....	.....	40	91	.....
			Average	7,400	.....	.....	.....	40	90	.....
		A. M.								
646	10-18	5:00	Tap in laboratory	95	.....	.....	.....	<5	78	0
648	10-18	9:00	Tap in laboratory	120	.....	.....	.....	<5	83	3
		P. M.								
651	10-18	1:00	Tap in laboratory	290	.....	.....	.....	<5	85	3
652	10-18	5:00	Tap in laboratory	130	.....	.....	.....	<5	92	3
654	10-18	8:00	Tap in laboratory	140	.....	.....	.....	<5	90	.....
			Average	155	.....	.....	.....	<5	86	3
		A. M.								
647	10-18	7:00	Fountain in square	70	.....	.....	.....	<5	81	4
655	10-19	5:00	Raw water	2,500	.....	.....	.....	30	90	0
		P. M.								
666	10-19	1:00	Raw water	3,500	0	0	.....	80	90	.....
672	10-19	9:00	Raw water	.....	.....	.....	.....	50	90	0
			Average	3,000	.....	.....	.....	54	90	.....
		A. M.								
659	10-19	9:00	Settled water	1,200	.....	.....	.....	.....	93	5
660	10-19	10:00	Settled water[2]	.....	.....	.....	.....	.....	100	14
		P. M.								
668	10-19	1:00	Settled water	1,525	.....	.....	.....	.....	96	7
	1906	A. M.								
656	10-19	5:00	Filtered water tap	105	.....	.....	0	<5	84	2
658	10-19	9:00	Filtered water tap	340	0	0	0	<5	88	3
661	10-19	10:00	Filtered water tap	.....	.....	.....	.....	<5	88	4

[1]N. W. wind blowing.
[2]After running off lime tanks.

TABLE NO. 24 — Concluded.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Phen. Alk.
		P. M.								
667	10-19	1:00	Filtered water tap.....	100	.....	.....	.....	<5	82	3
671	10-19	5:00	Filtered water tap.....	125	0	0	.....	<5	80	2
673	10-19	9:00	Filtered water tap.....	75	.....	.....	.....	<5	86	4
			Average	149	.....	.....	.....	<5	85	3
		A. M.								
657	10-19	7:30	Horse trough in square.....	1,200	.....	.....	0	<5	88	3
674	10-20	5:00	Raw water[2]	7,800	.....	.....	.....	70	90	0
677	10-20	8:30	Raw water	2,100	0	0	0	185	89	0
		P. M.								
682	10-20	1:30	Raw water	6,800	0	0	.....	210	88	0
			Average	5,600	.....	.....	.....	155	89	0
		A. M.								
680	10-20	10:00	Settled water	.....	.....	.....	.....	.....	88	2
675	10-20	5:00	Filtered water	235	.....	.....	0	<5	80	4
678	10-20	9:00	Filtered water	625	0	0	.....	<5	.....	.....
		P. M.								
683	10-20	1:30	Filtered water	525	0	0	0	<5	79	6
			Average	460	.....	.....	.....	<5	80	5
681	10-20	1:15	Fountain in square.....	1,300	0	0	0	<5	84	15
		A. M.								
684	10-21	11:00	Raw water	16,000	.....	.....	.....	225	88	0
685	10-21	11:00	Tap in laboratory.....	1,100	.....	.....	0	<5	88	3
		M.								
686	10-21	12:00	Horse trough in square....	.....	.....	.....	.....	<5	78	4
		A. M.								
865	12-13	9:15	Raw water from well.....	13,000	+	+	.....	70	89	.....
864	12-13	7:30	Tap at Franklin hotel.....	2,200	0	0	.....	.....	.....	.....
866	12-13	9:00	Tap in laboratory.....	2,900	0	0	.....	5	.....	.....
867	12-13	10:15	Tap at Dr. Hug's office.....	1,600	0	+	.....	.....	.....	.....
868	12-13	7:30	Tap at Dr. Hug's office.....	1,200	0	+	.....	.....	.....	.....

[2]High N. E. wind since mid-night.
Oct. (17-21) 1906, used 2.6 gr. of copperas per gallon and 1.0 gr. of lime per gallon.

DESCRIPTION OF NEW PURIFICATION PLANT.*

In 1905 the capacity of the old purification plant was exceeded by the quantity of water pumped and plans for a new purification plant of double its capacity were then drawn up. The first plant proposed comprised the construction of a preliminary settling basin on the shore of the lake, and a mechanical filter plant to be constructed at a higher elevation near the site of the old filter house. The settling basin was constructed in 1905, but for economical reasons it was decided to build the filter plant over the basin and not on the higher ground as was originally contemplated. On this account the general arrangement of the filter plant was limited, a fact which has had considerable bearing on the results obtained.

The new purification plant comprises a coagulating basin and clear well, formed by dividing the original settling basin into two compartments of nearly

*See Plate XII.

equal size; six gravity mechanical filters placed above the clear well, and a system for the preparation and application of the coagulants. While the use of the original intakes, forebay and high service pump are continued, two new pumps of the DeLaval impeller type are provided for low service. The new plant was built by the Pittsburg Filter Mfg. Co. and is housed in a substantial brick and concrete structure, located immediately on the shore of Lake Erie near the site of the old pumping plant.

Coagulants.

The coagulants used are copperas and lime, although the plant is arranged for the use of alum also.*

Means for Applying Coagulant.

The coagulant plant comprises a small wooden tank for slaking the lime and a small concrete tank for dissolving the copperas, two concrete tanks for storing the milk of lime, two smaller concrete tanks for storing the copperas solution, solution pumps, and a head tank. Both the slaking and the dissolving tanks have a capacity of approximately 150 gallons. All of the storage tanks are 8 feet in diameter, with a capacity of 376 gallons per foot depth. The milk of lime tanks have an available depth of 14.5 feet and the copperas tanks of 11 feet, giving a total available storage capacity of 5,450 gallons and 4,130 gallons, respectively.

In order to insure a circulation of the solution in the milk of lime tanks, a small impeller pump, 12 inches in diameter, driven by a motor, is provided in each tank. This is placed in a small vertical steel cylinder, the top of which is open, while the bottom terminates in a sheet metal plate in the form of a truncated cone. The head tank, which is provided to regulate the rate of application of the solutions, is placed in the roof trusses over the coagulant room. The solutions are pumped to this tank by two centrifugal pumps, driven by a single motor. Overflows are provided from the head tank and their outlets are carried down to a point near the bottom of the storage tanks.

The head tank is divided into two compartments by a vertical partition, and copperas is pumped into one compartment and lime into the other. The discharge from each compartment is regulated by a brass orifice. The copperas solution is carried by a 2½-inch pipe and discharged into the suction of the raw water pump,[1] while the milk of lime is carried through a similar pipe and discharged into the small compartment at the entrance of the coagulating basins.

Coagulating Basins.

As previously stated, the coagulating basins were formed by building a dividing wall through the center of the original settling basin. One of the compartments so formed was again divided into two compartments by another dividing wall. The larger of these compartments is approximately 40 feet wide, 55 feet long, and 27 feet deep, with a net capacity of 390,000 gallons; the smaller is approximately 20 feet wide, 55 feet long and 27 feet deep, and has a net capacity of approximately 190,000 gallons. When water is pumped through the basins at the rate of 6 million gallons per day, the storage or coagulating period in the basins is about two and one-half hours. As the distance traveled by the water is approximately 90 feet, its average velocity through the basins is theoretically 0.6 foot per minute. On account of the unusual depth of these basins, they are baffled with vertical partitions of re-

*Note — Since June, 1908, copperas and lime have been abandoned and alum has been used as coagulant.

[1]See Page 182.

inforced concrete construction, 4 inches thick, 20 feet apart, and so arranged that the water flows over the top of the first baffle and beneath the second.

Inlet. Particular attention has been paid to assuring a good distribution of the water through the basins. The force main from the raw water pump terminates in a small concrete compartment, 10 feet wide and 4 feet long. The discharge from this compartment passes through two sluice gates into two concrete vertical channels, the one leading to a distributing trough in the larger basin and the other to a similar trough in the smaller basin. These distributing troughs are of rectangular cross-section and are placed along the bottom of the coagulating basins. They contain openings 7 inches square and 2 feet apart in the larger compartment and 8 inches square and about 15 inches apart in the smaller compartment.

Outlet. The discharge from each coagulating basin is over a weir, which extends across the entire length of the wall separating the coagulating basins from the clear well. The discharge over these weirs enters concrete troughs or channels which carry the water through sluice gates and into a concrete conduit extending the entire length of the pipe gallery between the filters. Six 14-inch pipes are provided to carry the coagulated water from this conduit into the filters.

Drain. The bottom of the coagulating basin is so low that it is impossible to drain the basin by gravity into the lake. A sludge pump is provided to empty the basins when necessary. This is an impeller pump of the DeLaval type and is contained in a small well on the shore of the lake. It has a capacity of 3,000 gallons per minute and will readily lift very turbid waters.

FILTERS.

Capacity. The filter plant has a guaranteed capacity of six million gallons ing per day and comprises six rectangular filters of reinforced concrete construction. The three on the north side of the plant are somewhat smaller than those on the south side, from the fact that during construction there was a bulge in the wall of the settling basin on the north side, and it was impossible to construct the filters to the full size contemplated. The three on the north side of the plant are each 24.33 feet X 18 feet in section at the sand line with an area of 438 square feet each, while the three on the south side are 25.0 feet X 18 feet at the sand line with an area of 450 square feet each. The total filtering area provided is 2,664 square feet or 0.0612 acre.

Strainer System. Detailed drawings of the filters are shown in Plate XIII. It will be seen that the strainer system in each filter comprises a grid of 1½-inch wrought iron pipes, 6 inches apart, discharging into a main collector or manifold of cast iron, 6 inches in diameter. Into the wrought iron laterals are tapped at 6-inch intervals, §-inch holes into which are screwed perforated brass strainers of standard type patented by the contractor.

Filtering Material. On top of the strainer system is placed 6 inches of gravel, screened to a size not greater than §-inch and on top of this gravel is placed the filtering material 36" deep. The latter was obtained from Sea Girt, N. J., and is a sea sand. After five months' service it has an effective size of 0.44 m. m. and a uniformity coefficient of 1.4. An analysis of a sample of sand taken from a pile before placing in the filters showed an effective size of 0.40 m. m. and a uniformity coefficient of 1.6, and indicated an increase in effective size of .04 m. m. due to washing out of fine material in the beds.

Means for Washing. The wash water is obtained from the clear well and is applied to the filters by a DeLaval impeller pump. The pump originally installed was of too small capacity and the rate of application of the wash

water was but 4 inches vertical rise per minute in the filters, corresponding to 1,100 gallons per minute. In August, 1907, this pump was replaced by one of larger capacity, and since that time the wash water is applied at a rate corresponding to a vertical rise in the filter of 12 inches per minute. The gutters provided to remove the dirty wash water are of steel, and their tops are approximately 15 inches above the surface of the sand in the filters. The cross section of the gutters has an area of 1.1 square feet, and their total length is 54 feet; they have proven of just sufficient capacity to remove the wash water when applied at a rate of 12 inches per minute.

Agitation. Air is provided to assist in washing the filters, and is furnished by a DeLaval blower, under about 4 pounds per square inch pressure. It is carried to the filters by a 6-inch wrought iron pipe and is distributed over the surface by a grid of ½-inch brass pipes placed over the strainer system. In the brass laterals are drilled 1/16-inch holes, 6 inches apart.

Automatic Devices. Particular attention has been paid to providing the best possible forms of automatic controlling devices to assist in operating the plant. Each filter is provided with an automatic rate controller of the closed type. Loss of head gages are also provided to indicate the degree to which the filters are dirty. The valves of the filters are hydraulically operated and are controlled from operating tables.

Clear Well.

As in the old plant, the only storage of filtered water provided is in the clear well, which is located beneath the filters, and for which is used one of the compartments formed by the dividing wall built in the original settling basin. The clear well is approximately 62 feet square, and has a net capacity of 29,000 gallons per foot depth. Although the total depth of the clear well is approximately 20 feet, it is impossible to wash the filters when there is less than 4 feet of water in the clear well, and it is necessary to keep at least this depth of storage for fire protection; moreover, it is found that a greater depth than 14 feet in the clear well interferes with the action of the manifold sampling pump provided, so that the actual depth of storage available in the clear well is but 10 feet, or 290,000 gallons. This corresponds to a storage period of 70 minutes, when water is filtered at the rate of 6 million gallons per day.

EXAMINATIONS.

During the special investigation by the State Board of Health, the new purification plant has been visited four times; on June (3-8), July 25th, October (14-16) and December 13th, 1907. On but one of these visits, June (3-8), was there made a regular examination of the plant. The visits of June and October were made at the request of the Lorain officials that the State Board of Health take part in an official test of the new plant. After preparations for the examination of June were completed, word was received that the plant was not in condition for an official test; also in October it was found after the test had commenced that the plant was in a very unsatisfactory condition.

OPERATION.

The general method of operating the new purification plant is very similar to that of the old, as the raw water flows by gravity through the intakes into the forebay, and is pumped into the coagulating basins, receiving the coagulants on the way. It flows by gravity through the basins onto the filters, and through the filters into the clear well, from which it is pumped into the distributing system.

The operation of the filter house is distinct from that of the pump house, and is in general charge of a chemist, who directs the operation of the plant and also makes frequent bacterial and chemical analyses in order to determine the results obtained. The results of these analyses and various data relating to the operation of the plant are shown in Table No. 30. During the first four or five months operation, the chemist devoted the greater part of his time to tuning up the new plant, so that the daily records are not complete and some of the monthly averages shown are of fifteen or twenty days' analyses.

As no distributing reservoir is provided, the plant is operated continuously by three attendants on eight hour shifts.

Average Daily Consumption.

The quantity of water pumped on low service is greater than that pumped into the mains owing to the fact that filtered water from the clear well is used to wash the filters. In Table No. 25 are shown the average quantities of water pumped on both services during 1907, together with the quantity of filtered water used to wash the filters. This table shows a striking increase in the quantity of water consumed at Lorain, and it is apparent that the capacity of the new plant will soon be exceeded unless the consumption is reduced.*

TABLE NO. 25.

Gallons of Water Pumped.

Month.	Raw Water.	Filtered Water.	Wash Water.	Percentage of Wash Water.
1907				
January	.....	3,588,070	.....	10 (Est.)
February	.....	3,578,820	.....	10 "
March	.....	3,787,510	.....	10 "
April	.....	3,289,600	.....	10 "
May	3,685,500	3,360,610	373,400	10 "
June	3,857,040	3,471,340	385,700	10 "
July	4,123,500	3,811,780	311,720	7.6
August	4,214,500	3,975,940	238,560	5.7
September	4,344,880	3,916,360	428,520	9.9
October	4,564,330	4,161,490	402,840	8.8
November	4,967,250	4,498,720	468,530	9.4
December	5,644,290	5,365,290	279,000	4.9

Method of Applying Coagulants.

The method of applying the coagulants has been practically the same during the special investigation. The routine procedure for preparing the milk of lime is as follows. Into the slaking tank containing approximately 150 gallons of water of the same temperature as that in the mains, there are placed the charges of unslaked lime varying from 100 to 400 pounds. The mixture is thoroughly stirred for about 10 minutes, and the resulting strong milk of lime then discharged into one of the lime storage tanks, which are used alternately and where the strong milk of lime is diluted to 5,450 gallons. The motor driving the im-

*Note: In the spring of 1908 the daily consumption was largely reduced by repairing leaky mains.

peller in the storage tank is started in operation and maintains a constant circulation of the solution in the tank. The efficiency of the agitation as shown by variations in the strength of the lime solution was determined during the examination of June (3-8).

From the storage tanks the diluted milk of lime is pumped to the head tank and flows by gravity through the solution pipes into the small concrete compartment provided at the end of the raw water force main. The quantity of lime solution applied is very accurately regulated by the adjustable orifice in the head tank. It is the custom to operate the solution pump at a rate faster than is required to supply the solution, and the excess quantity returns to the solution tank through the overflow and assists in maintaining a circulation in the tanks. It is possible to vary the quantity of lime applied by changing either the strength of the milk of lime or the rate at which it is applied.

The methods used for applying the copperas are essentially the same as for the lime. The charges, generally 200 to 400 pounds each, are placed in the dissolving tank which contains about 150 gallons of water, and the resulting strong solution is then run down into one of the storage tanks, and is diluted to 4,130 gallons. The remaining procedure is the same as that used for applying the lime. No agitation is provided in the storage tanks for copperas solution, and the efficiency of the system in maintaining a constant strength of solution was determined by frequent analyses during the examination of June (3-8).

Quantity of Coagulant Used.

The method generally employed to coagulate the water in the new plant is similar to that formerly used in the old plant, except that it has generally been the custom to use a somewhat greater quantity of lime. The average quantity of copperas used during 1907, as shown in Table No. 30, was 1.89 grains per gallon and of lime 0.95 grain per gallon, a quantity considerably less than that used in the old plant during 1905-6. The ratio of the quantity of lime applied to that of the copperas, during 1905-6, was 0.40, while during 1907 this ratio was 0.50. During February, March, April and June, 1907, even a greater relative quantity of lime was used, and there has sometimes resulted an average quantity of 12 parts per million of mono carbonates in the filtered water. This excessive use of lime is a very important point and one that has probably had considerable influence on the efficiency of the results obtained by the plant.

Coagulating Basins.

The operation of the coagulating basins requires little discussion, although the results obtained by the basins have a very important influence on the purification obtained by the plant. In the absence of satisfactory controlling devices, there results a considerable fluctuation in the level of the water on the filters, a fact which has, however, probably very little significance in the results obtained. It is necessary to occasionally clean the basins, which is accomplished by pumping out the water by means of the sludge pump, and then flushing out the sediment which remains in the bottom of the basins. When one of the basins was cleaned in June, 1907, the accumulated deposit was 6 feet deep in places, particularly near the vertical baffle which extends to the bottom of the basins. Although the deposit formed in the basins at Youngstown, where alum is used as a coagulant flows by gravity together with the water when the basin is emptied through the drain, the deposit that accumulates from coagulation with lime and copperas at Lorain is much heavier and will not flow by gravity, so that it is necessary to flush it out by means of a fire hose.

FILTERS.

The operation of the filters requires that they maintain as nearly as possible the maximum efficient rate, and that they be properly flushed when dirty.

Rate of Filtration. As the filters are provided with automatic rate controllers, the actual rates obtained require little attention on the part of the operators after the controllers are once adjusted. During the examination of June (3-8), 1907, although the controllers were in service and were intended to maintain a constant rate of approximately 100 million gallons per acre per day, the actual average rates obtained were considerable less from the fact that it was necessary to continue the operation of the filters after they were dirty. On this account the rate controllers served to limit the maximum rate, but the average rate obtained was considerable less than the maximum and was approximately 70 million gallons per acre per day.

Washing. Considerable difficulty has been encountered in obtaining a satisfactory washing system for the filters, as the first wash water pump provided was too small capacity and it was found impossible to obtain a satisfactory distribution of the air. With the new pump provided in August, 1907, the rate of application of the wash water is 12 inches vertical rise per minute in the filters, and the water is applied generally for about 8 minutes, so that the quantity of water per wash is 26,600 gallons, corresponding to a displacement of 8.0 feet in the filter.

Although the loss of head gages have proven very satisfactory, there has been considerable difference of opinion among those operating the plant as to the maximum loss of head that should occur between washing. It has sometimes been the custom to wash the filters when the loss of head was about 12 or 13 feet, but the evidence indicates that when the filters are run so long a greater quantity of wash water is required than when the period between washing is less.

In Table No. 25 has been shown the quantity of water actually used in washing the filters.

CHARACTER OF RAW WATER.

The character of the raw water has been discussed in the report on the old purification plant. The results obtained by the daily analyses during 1907 are shown in Table No. 30. These analyses indicate a somewhat more turbid water than the average and also one containing larger numbers of bacteria. In general it may be said that the extension of the west break-water at the mouth of the Black River during 1906 has caused a more direct flow of river water over the intake of the water-works, and that the water has been more difficult to treat during 1907 than at any time previous.

EFFICIENCIES.

GUARANTEE.

The contract for the installation of the new plant contains the following:

"On completion of the work to be performed, the contractors shall furnish an operator for fifteen (15) days to superintend the operation of the plant, during which time the city may have the water tested and analyzed to determine the degree of purity obtained, which shall be as follows:

> "The purification obtained shall be such that in no case shall the average number of bacteria in the filtrate exceed 100 per cubic centimetre, except when the number of bacteria in the applied water

shall exceed 2,500 per c. c. in which event the average reduction of bacteria in the filtrate shall be at least 98 per cent.

"Not more than 5 per cent. of the individual samples of filtrate shall show more than 150 bacteria per c. c., nor more than 5 per cent. of the samples of the filtrate shall show an efficiency as low as 90 per cent. No trace of undecomposed coagulant shall be left in the filtrate nor shall the filtrate show any increase in iron or aluminum. The filtrate shall show no acid. The filtered water shall be bright, clear and practically free from color, turbidity or matter in suspension and shall be furnished at the rate of 6,000,000 gallons of water per day."

Methods of Applying Lime.

During the examination of June (3-8), 1907, hourly samples of the milk of lime were obtained from the head tank, and were titrated at the plant for available CaO. The results of these titrations, together with the number of samples are shown in Table No. 26.

During this examination the methods of applying the coagulant were similar to that previously described, and the charges used were of 400 pounds. The theoretical strength of the milk of lime, assuming that the dry chemical contained 100 per cent. CaO, was 514 grains per gallon. The table also contains the maximum and minimum strengths of the solution as determined, and it will be seen that there was a very considerable variation which would indicate that the methods provided for obtaining a constant circulation in the storage tanks were not efficient. The poor results obtained, however, were due to the use both of a poor grade of lime, which essayed about 81 per cent. CaO, and also to the fact that too great a quantity of lime was used in each charge. The greatest variations in strength occurred when the solution tanks were changed.

TABLE NO. 26.

Strength of Lime Solutions.

Date.	No. of Samples.	Strength of Solution. Grains per Gallon (CaO).		
		Average.	Maximum.	Minimum.
June 4	6	312	395	100
June 5	10	293	378	172
June 6	9	254	424	161

Twice during this examination the lime suction pipe, which is of 2½-inch wrought iron, was clogged by the milk of lime and the solution pump put out of service. This was undoubtedly due to the use of milk of lime in greater strength than can be successfully handled by the pump. There is a considerable suction lift for the pump, particularly when the solution tanks are nearly empty, and the use of a strong solution of lime gives greater friction than a weak solution and adds a considerable friction head to the actual gravity lift. It was

stated by the operators that no difficulty is obtained in handling the milk of lime when charges of from 100 to 200 pounds are used.

Methods of Applying Copperas.

The efficiency of the methods for handling copperas were tested in a manner similar to that used for the methods of applying lime, and in Table No. 27 are shown the average, maximum and minimum strengths obtained. As the charges of copperas were of 400 pounds each, the theoretical strength, assuming that the dry chemical contained 100 per cent. copperas, was 677 grains per gallon. It was found that the copperas solutions were stronger at the bottom than at the top of the tanks, due to lack of mechanical agitation, and as the tanks were not emptied, the average strength of the solutions was greater than the theoretical strength. The results obtained indicate considerable variations in the strengths of the solutions, particularly when the storage tanks were changed.

TABLE NO. 27.

Strength of Copperas Solutions.

Date.	No. of Samples.	Strength of Copperas Solution. Grains per Gallon.		
		Average.	Maximum.	Minimum.
June 4	6	692	692	692
June 5	10	701	2,430	645
June 6	9	698	725	660

Deposits in Filters.

As previously mentioned, there was a greater proportion of lime used during 1907 than during 1905-6, although the treatment during 1906 had caused an accumulation of "after deposits" of lime in the filter sand in the old plant. The continued use of large quantities of lime was recommended by Mr. C. Arthur Brown, as being necessary in order to secure a proper coagulation of the water.

In October, 1907, after an official test of the plant had been started, examination showed that the sand in the filters was in very poor condition, and that it contained accumulations of red mud in pockets. These accumulations were found in all parts of the filters, particularly along the sides and bottom and during washing they gathered in the form of small balls on the surface of the sand. Representative samples of these mud balls were found on analysis to contain 13.4 per cent carbonate of lime ($CaCO_3$) and 2.4 per cent. metallic iron (Fe). A further examination revealed the fact that the air pipes were covered on the outside with a very hard scale, consisting principally of lime.

At the time of the examination in October, 1907, the plant was run for a few days using alum as a coagulant. Although the water on the filters contained 15 parts per million less alkalinity than that in the lake (caused by the

alum), the effluent from the filters had practically the same alkalinity as the water in the lake. This increase of alkalinity of the filtered over the applied water was caused by the dissolving out of lime from the filters. Although alum was applied for 11 days at an average rate of 1.7 grains per gallon, at the end of this time the filtered water still contained 10 parts per million more alkalinity than the applied water. This fact is significant as it indicates the extent of the "after deposits" of lime in the filters.

In order to remove these deposits in the filters they were all overhauled in turn and the accumulations of mud and coagulant removed by alternate washing and scraping of the surface of the sand. Where pockets of mud were found the sand was removed and thrown away. The air pipes also were all removed and cleaned. Since October, 1907, less lime has been applied and it is the custom to maintain but a small quantity of mono carbonates in the filtered water.

Deposits in Raw Water Pumps.

On several occasions when the cases of the raw water pumps were opened for examination and repairs, it was found that the impellers were covered with a dark red scale varying in thickness from one-quarter to one-half inch. This scale forms by deposits of iron which is applied to the raw water suction near the pumps. It is quite probable that these incrustations effect the efficiency of the pumps, as slight changes in the form of the impellers cause considerable changes in capacity. They could be eliminated by changing the application of the copperas solution to a point beyond the pumps.*

Coagulating Basins.

Although the operation of the coagulating basins require little attention on the part of the attendants, the efficiencies of removal, both of bacteria and suspended matters largely effect the results obtained by the plant. From the evidence contained in the daily records in Table No, 30 it will be seen that the average bacterial removal by the basins from April to December, 1907, was but 39 per cent. During but two months, May and June, were satisfactory removals obtained, and these were followed in July by a period during which the numbers of bacteria in the applied water were greater than in the raw water. In August, also, the average removals obtained were small. There is apparently no relation between the bacterial removal by the basins and the quantity of coagulant used.

Efficiencies of Basins during Examination of June, 1907. Unusually interesting conditions prevailed during the examination of June, 1907. On the night of June 3rd, owing to an error in the manipulation of the plant, the coagulation in the basins was lost, and there was no visible coagulation in the basins until about 4:00 P. M., June 4th. It is a well-known fact that when once the flock in a coagulating basin is lost, it is difficult to restore it. Although it was advised that the addition of clay would assist in quickly restoring the coagulation, the method used was to increase the quantity of lime applied until it was very nearly equal to the quantity of copperas. The actual quantities of coagulant used during this examination are shown in Table No. 28.

*Note: In the spring of 1908 the point of application of the copperas was moved beyond the pump and trouble from deposit thus eliminated.

TABLE NO. 28.

Quantities of Coagulants Applied.

Date. 1907.	Water Pumped, Gals. p. Min.	Lime (CaO).			Copperas.		
		Gals. Sol. p. Min.	Strength Gr. p. Gal.	Gr. p. Gal. Applied.	Gals. Sol. p. Min.	Strength Gr. p. Gal.	Gr. p. Gal. Applied.
June 4	3,260	26.7	312	2.55	13.5	692	2.86
June 5	3,260	12.6	293	1.13	12:8	701	2.75
June 6	3,440	17.65	254	1.31	12.9	698	2.60

During the examination samples of applied water were taken from the top of Filter No. 2. The analyses obtained on June 4th are of considerable interest as showing a very small reduction in the suspended matters even with the large quantities of coagulant used. Moreover, the average quantity of mono carbonates in the applied water on June 4th was 36 parts per million, and in the filtered water 22 parts per million. These results indicate both an excessive use of lime and a deposition in the filters. On June 4th, there was also but a very slight reduction in the quantity of dissolved color. On June 5th the coagulation had been restored and the improvement in the removals obtained is indicated both by the bacterial content of the applied water and its turbidity. The average quantity of mono carbonates contained in the applied water was 36 parts per million. On June 6th, although the ratio of the quantity of lime to copperas applied was 0.50, the applied water contained 34 parts per million mono carbonates, and the filtered water but 16 parts per million.

While the results obtained during this examination are abnormal from the fact that there was no coagulation during June 4th, yet they indicate in a general way the results that are obtained when an excess quantity of lime is applied. It is apparent that the removal of dissolved color is but slight, and that the quantity of mono carbonates in the filtered water is considerably less than in the applied water, a fact which indicates an absorption of free CO_2 and the deposition of lime in the filters.

In conclusion it should be said that the results obtained by the coagulating basins during 1907 have been very unsatisfactory and that at the time of writing this report the reason for the poor results obtained is not understood. It is probable that the "up and down" system of baffling does not give an efficient displacement in the basins, and that with a different arrangement of baffles better results would obtain. In this connection it is of interest to note that the coagulating basins are practically sealed, a fact which may interfere with the oxidation necessary when copperas and lime are used as coagulants.

OFFICIAL TESTS OF PLANT.

Subsequent to the examination of October, 1907, two official tests of the plant have been made by the Lorain authorities. The one was begun on November 17th and continued for fifteen days, during which time copperas and lime were used as coagulants. The copperas was applied at an average rate of approximately 2 grains per gallon. During the test samples of coagulated water

were obtained from the conduit and of the filtered water from the sampling stand and also from a tap in the laboratory.

The following table shows the efficiencies of bacterial removal obtained during this official test.

Coagulated Water	39.05%	removal
Clear Well	96.63	"
Tap in Laboratory	96.67	"
Average Filters	97.02	"

From the evidence obtained in this examination, the filter plant was not accepted as the efficiencies did not fulfill the specifications.

In January, 1908, another official test of the plant was run for fifteen days, during which approximately 2.5 grains of alum per gallon were applied. The average results obtained from similar sampling points are shown in the following table.

Coagulated Water	80.8%	removal
Clear Well	98.4	"
Laboratory Tap	98.3	"
Average Filters	98.7	"

The most striking point in these two tables is the greater efficiency of the coagulating basins when alum was used as a coagulant.

Filters.

The results obtained by the filters have been largely influenced by the methods used for coagulating the water and also by difficulties encountered in obtaining a satisfactory system of washing.

Rate Controllers. It has been stated by the operators that the rate controllers have been generally satisfactory, although occasionally they stick and refuse to open, a condition which is generally caused by the leakage of sand from the filters. From tests made during the early operation of the plant it is apparent that there is some variation in the rate of the different filters, and that the rate of filtration tends to decrease with the length of the run between washings.

Washing. Although it was intended to run an official test of the plant in June, 1907, it was found at that time that the sand in the filters contained many hard spots which it was impossible to remove by the ordinary methods of washing. During the examination of June, the operators endeavored to remove these hard spots with frequent long applications of wash water, and the average quantity of water used to flush the filters was approximately 25 per cent. of the quantity filtered. The loss of head gages indicated a rapid increase in the loss of head, particularly after washing, when in 15 minutes the head frequently increased to about 5 feet. On this account much difficulty was experienced in obtaining a sufficient quantity of water through the filters.

These hard spots in the sand were due principally to an insufficient rate of application of the wash water, and a new pump was provided in August, 1907. With this pump the rate of washing was increased from 4 to 12 inches per minute.

The condition of the sand in October, was largely due to the poor washing of the filters previous to August when the new pump was provided. Although the sand had been worked over previous to October, and the hard spots largely eliminated, there still remained small deposits, especially along the sides and bottom of the filters, and these were gradually removed in October by alternately

washing and scraping the sand. There is still some difficulty in obtaining a satisfactory distribution of air during washing.

Bacterial Efficiencies. The average bacterial removals accomplished by the filters are well indicated in Table No. 30. The average removal by the plant was but 87 per cent. The results indicate considerable variations in the efficiencies obtained, and in general it may be said that the work of the plant has been unsatisfactory during the entire year, and has been influenced largely by the poor results obtained by the coagulating basins.

It is of interest to note the large per cent. positive tests for coli in the filtered water. The general unwholesomeness of the water is also indicated by the high typhoid mortality during 1907, as shown in Table No. 20.

SUMMARY OF INVESTIGATION OF NEW PLANT.

There are several factors that have had an important part in causing the generally poor results obtained by the new purification plant, among which should be included the poor means provided for washing the filters until August, 1907, the improper use of coagulants, and the poor efficiencies obtained by the coagulating basins.

The poor washing of the filters during the summer resulted in the formation of numerous hard spots in the sand and caused uneven rates of filtration and a poor distribution of the air used for agitation. It is probable also that, as was found at Marietta, there was a considerable growth of bacteria in these hard spots, a fact which might account for some of the bacteria in the filtered water. With the improved methods of washing, less trouble has been experienced in obtaining satisfactory washing when the plant is properly operated.

The use of too great a quantity of lime resulted in the formation of incrustants on the air pipes, causing a poor distribution of the air and considerably effecting the efficiency of the washing system. The accumulations in the filters contained considerable lime and may also have resulted in part from improper use of the coagulants. The extent of these deposits is indicated by the continued absorption of lime by the filtered water in both October, 1906, and January, 1907, when alum was used as a coagulant.

The principal factor in causing the poor results has been the unsatisfactory operation of the coagulating basins. The evidence obtained during the official tests and subsequent operation of the plant in 1908 indicates a much better bacterial removal by the basins with alum than with copperas and lime, a fact which tends to show that the difficulties encountered with the latter treatment are due to chemical and not to mechanical effects. Subsequent to the special investigation of the Board the Lake Erie water at Lorain has been found to contain at times but 1.5 parts per million of dissolved oxygen. This low oxygen content of the raw water is thought to have a deciding influence on the treatment with copperas for which oxygen is required to complete the chemical reaction.

That the poor efficiencies obtained have resulted in an unwholesome water supply is indicated by the marked increase in typhoid mortality to 75 per 100,000 during 1907. This would indicate that the provision of the filter plant had induced a false sense of security on the part of the community.

The evidence obtained during the special investigation indicates that much better results, and a much more wholesome water may be obtained using alum as a coagulant than using copperas and lime. The use of these latter coagulants was continued contrary to the recommendations by the State Board of Health in December, 1906, as the Lorain authorities were of the opinion that copperas and lime were more efficient and economical. It is their intention to continue comparative tests of the coagulants.*

*NOTE: The results obtained with alum during 1908 have been so much better than with copperas and lime that the latter treatment has been abandoned.

COST OF INSTALLATION AND OPERATION OF NEW PLANT.

The total cost of the new purification plant including the entire contents of the filter house and foundations was $85,000. This included also the construction of the original settling basin which cost the city $10,000.

The cost of operating the filter house, as obtained from the report of the superintendent for the year 1907, is shown in Table No. 29. It will be seen to include the cost of labor, coagulants, coal and miscellaneous labor and supplies. The latter item includes the labor necessary for tuning up the plant and also part of that incurred by the necessary overhauling of the filters in the fall of 1907. In the second part of the table is shown the itemized cost per million gallons. It will be seen that neither of these tables include interest charges.

TABLE NO. 29.

Cost of Operating Filter House — 1907.

Chemist — $95 per mo		$1,140
Three operators — $65 per mo		2,340
Coagulants		2,921
Coal (973 tons — $1.94)		1,888
Miscellaneous labor and supplies		2,062
Total cost		$10,351
Total consumption	1,425,000,000 gallons	
Total cost per million gallons		$7 26
Includes labor	$2 44	
Coagulants	2 05	
Coal	1 33	
Miscellaneous labor and supplies	1 45	

TABLE NO. 30.

Lorain — Operation of Plant — 1907.

Month.	Average Daily Consumption.	Coagulants. Grains per Gal.		Parts per Million.				Bacteria per C. C.					Coli in 1 C.C. Per Cent. Positive Tests.	
				Lake Water.		Effluent.					Av. Daily Reductions. Per Cent.			
		Copperas.	Lime.	Turbidity.	Alkalinity.	Total Carb.	Mono Carb.	Lake.	Settled Water	Effluent.[3]	Basins.	Filters.	Lake.	Effluent.
1907.														
Jan.	3,588,070	2.65	1.48	182	78	70	6	6,700	.....	950	.....	86	42	12
Feb.	3,578,820	1.96	1.06	52	89	86	4	5,000	.....	400	.....	92	67	12
Mar.	3,787,510	2.22	1.10	170	82	79	6	5,000	.....	825	.....	85	58	15
Apr.[1]	3,289,600	2.23	1.43	249	90	87	7	6,500	3,000	450	63	90	67	14
May	3,360,610	1.46	0.62	.....	90	84	7	10,500	2,400	525	61	91	33	0
June	3,471,340	1.89	1.33	.....	89	79	12	7,400	1,650	350	46	82	57	3
July	3,811,780	1.42	0.82	.....	88	88	9	1,650	2,100	350	Negative	69	69	9
Aug.	3,975,940	1.87	0.69	.....	86	88	6	2,100	1,500	250	31	88	71	20
Sept.	3,916,360	1.48[2]	0.56	.....	88	90	6	2,300	1,250	165	52	88	60	0
Oct.	4,161,490	1.24[2]	0.57	62	95	93	0	4,300	2,800	625	39	88	75	14
Nov.	4,498,720	1.82	0.76	83	94	89	5	5,600	3,500	240	29	92	41	5
Dec.	5,365,290	2.46	1.09	147	89	76	5	9,000	4,300	400	32	92	53	4
Aver.	3,900,462	1.89	0.95	135	88	84	6	5,510	2,500	460	39[4]	87	58	9

[1] Use of old plant discontinued April 8th.
[2] During 3 days in Sept. used alum at aver. rate of 1.93 gr. per gallon.
During 8 days in October used alum at average rate of 1.60 grains per gallon.
[3] Samples from tap in laboratory.
[4] Efficiency of basins determined by 249 analyses; 70 negative results were obtained — 28 per cent.

TABLE NO. 31.

Lorain — Analyses During Examinations.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C.C.	Colon in .5 C.C.	1 C.C.	2 C.C.	100 C.C.	Parts per Million. Col.	Turb.	Alk.	Phen. Alk.	CO_2	Chlor.
	1907	A. M.												
2	6-4	10:00	Raw water[1]	48,000	+	+	+	....	45	145	77	....	8	15
		M.												
5	6-4	12:00	Raw water[2]	23,000	+	+	+	....	35	120	81	....	1	15
		P. M.												
8	6-4	2:00	Raw water	20,000	+	+	+	....	35	110	82	....	1.5	17
11	6-4	3:00	Raw water	16,000	+	+	+	....	35	100	83	....	2	20
14	6-4	4:00	Raw water	24,000	+	+	+	....	40	100	84	....	2	17
17	6-4	5:00	Raw water[3]	14,500	+	+	+	....	35	105	83	....	2	13
20	6-4	6:00	Raw water	13,300	+	+	+	....	32	100	82	....	3	20
			Average	24,000	+	+	+	....	37	115	82	....	2	17
		A. M.												
3	6-4	10:00	Set. water top filter[4]	15,000	....	....	....	....	....	90	89	8	....	....
		M.												
6	6-4	12:00	Set. water top filter[4]	10,000	....	....	....	....	....	100	82	24	....	....
		P. M.												
9	6-4	2:00	Set. water top filter[4]	9,100	....	....	....	....	....	90	72	20	....	....
12	6-4	3:00	Set. water top filter[4]	4,000	....	....	....	....	....	55	59	15	....	....
15	6-4	4:00	Set. water top filter[5]	3,000	....	....	....	....	....	30—	58	18	....	....
18	6-4	5:00	Set. water top filter[5]	4,400	....	....	....	....	....	30	56	17	....	....
21	6-4	6:00	Set. water, conduit.	8,000	....	....	....	....	....	50	66	22	6	....
			Average	8,450	....	....	....	....	....	70	72	18	—	—
		A. M.												
4	6-4	10:00	Filtered water at pump	11,000	....	....	....	+	30	5±	80	8	....	....
		M.												
7	6-4	12:00	Filtered water at pump	3,700	....	....	....	0	30	5±	82	7	....	....
		P. M.												
10	6-4	2:00	Filtered water at pump	4,000	....	....	....	+	30	5±	65	16	....	....
13	6-4	3:00	Filtered water at pump	4,700	....	....	....	+	30	5±	59	12	....	....
16	6-4	4:00	Filtered water at pump	1,500	....	....	....	+	30	5—	55	9	....	....
19	6-4	5:00	Filtered water at pump	1,600	....	....	....	+	30	5—	55	11	....	....
22	6-4	6:00	Filtered water at pump	1,600	....	....	....	+	30	5—	50	13	....	....
			Average	4,370	....	....	....	....	30	5	67	11	....	....

[1] Northeast wind blowing.
[2] Rain began at 11:00 A. M.
[3] Northwest wind blowing briskly.
[4] No coagulation in basins.
[5] Coagulation visible.

TABLE NO. 31 — Continued.

Collected. Date.	Hr.	Source.	Parts per Million. Col.	Turb.	Alk.	Phen. Alk.	CO_2	Fe.	Incr.
1907									
6-4	.....	Composite raw water.....	35	110	82	.....	2	1.5	42.5
6-4	.....	Composite filtered water.....	30	5±	66	8	.....	1.0	50.
	P. M.								
6-8	10:00	Tap at Harden's restaurant.....	30	5±	43	9	.....	0.5	.....

TABLE NO. 31 — Continued.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C.C.	Colon in .5 C.C.	1 C.C.	2 C.C.	100 C.C.	Parts per Million. Col	Turb.	Alk.	CO_2	Cl.
	1907	A. M.											
24	6-5	8:00	Raw water at forebay..	9,000	+	+	+	....	25	240	90	0.5	14
27	6-5	9:00	Raw water at forebay..	6,000	....	....	....	....	12	240	91	0.5	15
30	6-5	10:00	Raw water at forebay..	11,300	+	+	+	....	10	190	86	0.5	15
33	6-5	11:00	Raw water at sample pump	13,000	....	....	....	....	12	200	89	1.	18
		P. M.											
37	6-5	1:00	Raw water at sample pump	11,000	0	+	+	....	12	175	90	0.5	14
40	6-5	2:00	Raw water at forebay..	9,900	....	....	....	....	12	165	89	1.	17
43	6-5	3:00	Raw water at forebay..	12,300	+	+	+	....	12	170	90	0.5	18
46	6-5	4:00	Raw water at forebay..	15,500	....	....	....	....	12	170	89	0.5	14
			Average	11,000	+	+	+	....	14	196	89	0.5	15
		A. M.										Ph. Alk.	
25	6-5	8:00	Set. water top of filter No. 2	1,200	....	....	....	....	....	25±	91	13	....
28	6-5	9:00	Set. water top of filter No. 2	520	....	....	....	....	....	25±	90	17	....
31	6-5	10:00	Set. water top of filter No. 2	400	....	....	....	....	....	25±	86	21	....
34	6-5	11:00	Set. water top filter No. 2	1,200	....	....	....	....	....	25±	85	23	....
		P. M.											
38	6-5	1:00	Set. water top of filter No. 2	1,200	....	....	....	....	....	25±	91	17	....
41	6-5	2:00	Set water top of filter No. 2	420	....	....	....	....	....	25±	92	19	....
44	6-5	3:00	Set. water top of filter No. 2	1,400	....	....	....	....	....	30	81	21	....
47	6-5	4:00	Set. water top of filter No. 2	2,700	....	....	....	....	....	40	84	12	....
			Average	1,150	....	....	....	....	....	25	88	18	....
		A. M.										Ph. Alk.	
26	6-5	8:00	Filtered water	250	....	....	....	+	25	5—	83	9	....
29	6-5	9:00	Filtered water	400	....	....	....	+	10	<5	83	7	....
32	6-5	10:00	Filtered water	400	....	....	....	+	8	<5	80	5	....
35	6-5	11:00	Filtered water	400	....	....	....	+	8	<5	75	11	....
		M.											
36	6-5	12:00	Filtered water	325	....	....	....	+	8	<5	73	14	....
		P. M.											
39	6-5	1:00	Filtered water	250	....	....	....	0	6	<5	72	12	....
42	6-5	2:00	Filtered water	200	....	....	....	+	8	<5	74	7	....
45	6-5	3:00	Filtered water	350	....	....	....	+	6	<5	74	9	....
48	6-5	4:00	Filtered water	200	....	....	....	+	6	<5	74	7	....
50	6-5	5:00	Filtered water	275	....	....	....	+	8	<5	73	9	....
			Average	305	....	....	....	+	9	<5	76	9	....

TABLE NO. 31 — Continued.

Collected. Date.	Hr.	Source.	Bacteria per C.C.	Parts per Million. Color.	Turb.	Alk.	Phen. Alk.	Fe.	Incr.
6-5	.....	Composite raw water.....	.....	.....	200	91.5	.....	0.90	29
6-5	.....	Composite effluent	.....	8	<5	78.	8	0.15	49
6-5	A. M. 7:00	Tap at Mrs. Barrow's residence.....	600	20	5—	84	13	.....	.....

TABLE NO. 31 — Continued.

Field No.	Collected. Date.	Hour.	Source.	Bacteria per C.C.	Colon in .5 C.C.	1 C.C.	2 C.C.	100 C.C.	Parts per Million. Color.	Turb.	Alk.	CO_2	Cl.
	1907	A. M.											
51	6-6	8:00	Raw water[1]	5,400	+	+	+	....	12	140	87	1.	13
55	6-6	10:00	Raw water	9,800	+	+	+	....	....	130	84	1.5	14
		M.											
59	6-6	12:00	Raw water	5,000	0	+	+	....	17	110	86	1.	....
		P. M.											
63	6-6	2:00	Raw water	3,800	+	+	+	....	23	110	85	0.	13
67	6-6	4:00	Raw water	7,500	0	+	+	....	12	120	85	0.	13
			Average	6,300	....	+	+	....	16	120	85	0.7	13
												Ph. Alk.	
		A. M.											
52	6-6	8:00	Set. water top filter No. 2	3,200	....	....	....	+	....	40	81	7	....
56	6-6	10:00	Set. water top filter No. 2	1,200	....	....	....	+	6	40	84	14	....
		M.											
60	6-6	12:00	Set. water top filter No. 2	2,000	....	....	....	....	8	40	77	19	....
		P. M.											
64	6-6	2:00	Set. water top filter No. 2	960	....	....	....	....	....	40	86	23	....
68	6-6	4:00	Set. water top filter No. 2	2,500	....	....	....	....	....	40	68	20	....
			Average	1,975	....	....	....	....	7	40	79	17	....
		A. M.											
53	6-6	8:00	Filtered water	425	....	....	....	+	6	<5	73	5	....
54	6-6	9:00	Filtered water	475	....	....	....	+	6	<5	78	9	....
57	6-6	10:00	Filtered water	1,400	....	....	....	0	6	<5	77	2	....
58	6-6	11:00	Filtered water	250	....	....	....	+	6	<5	76	11	....
		M.											
61	6-6	12:00	Filtered water	180	....	....	....	+	8	<5	73	7	....
		P. M.											
62	6-6	1:00	Filtered water	240	....	....	....	+	8	<5	67	5	....
65	6-6	2:00	Filtered water	325	....	....	....	+	9	<5	64	17	....
66	6-6	3:00	Filtered water	525	....	....	....	+	9	<5	66	10	....
69	6-6	4:00	Filtered water	425	....	....	....	+	9	<5	70	8	....
70	6-6	5:00	Filtered water	375	....	....	....	+	10	<5	70	8	....
			Average	460	....	....	....	+	8	<5	71	8	....

[1]N. W. wind blowing strongly.

TABLE NO. 31 — Concluded.

Collected. Date.	Hr.	Source.	Bacteria per C.C.	Parts per Million. Color	Turb.	Alk.	Phen Alk.	Fe.	Incr.
6-6	.....	Composite raw water	.....	18	120	86	0	1.5	42
6-6	.....	Composite effluent	.....	9	<5	75	7	0.20	54

NOTE — For quantities of coagulants used see page 183.

MARIETTA.

Marietta, the county seat of Washington County, is in the southern part of Ohio, at the mouth of the Muskingum River, where it joins the Ohio. Its population in 1906 was estimated at 15,500. Marietta marks the oldest settlement in the state, and is a typical river town. For several years it experienced a period of great prosperity from the oil industry, which, however, has since declined. Although containing several small manufacturies, the city is the center of a fruit and produce growing industry.

HISTORICAL.

Original Installation.

The waterworks were first installed by the city of Marietta in 1890, and the supply was taken directly from the Ohio River without purification. The pumping station, containing two high service pumps, together with the necessary boilers and machinery, is a substantial brick structure, located about one mile above the center of the city on the shore of the Ohio River. Besides the pumping plant and distribution system, two steel tanks of 1,500,000 gallons capacity, for equalizing and storage purposes, were built on Gross's Hill about 1¼ miles back from the pumping station.

Conditions Leading to Purification.

The watershed of the Ohio River above Marietta contains 26,730 square miles, on which there is an urban population of 1,358,000, which corresponds to 51 per square mile. There are several small communities along the shore of the river and its tributaries, and in general the river lands are cultivated. Sistersville, with a population of 3,000, 32 miles above Marietta is the nearest source of pollution of the water supply and it has a municipal water supply and system of sanitary sewers. The next communities of any size on the watershed are Bellaire and Wheeling, with a population of 20,000 and 45,000, respectively, 75 miles above Marietta.

The most serious local pollution at Marietta is from Duck Creek into which is discharged the effluent from a septic tank, in which is treated the sewage from the Washington County Infirmary. This institution has about 80 inhabitants, and the amount of sewage treated daily is about 2,500 gallons. The effluent from the tank is discharged directly into Duck Creek, about 1,500 feet above the intake of the Marietta waterworks. During the special investigation by the State Board of Health, there has been very little purification of the sewage from the infirmary, as the septic tank serves merely to retain the coarser solid matters, on which account there is always a danger of serious pollution of the Ohio River at the Marietta waterworks intake, especially during periods of low flow in the river, when the proportional amount of sewage is greater than during flood stages.

Not only is the Ohio River unsuitable as a source of supply at Marietta on account of the danger of pollution from domestic wastes, but, during the greater part of the year, the water carries large amounts of suspended matters, which make it very undesirable for domestic use.

Plans for the purification of the water supply were submitted to the State Board of Health by the Marietta authorities in 1901, and comprised gravity mechanical filters, using lime and iron as coagulants. These were approved by the Board on the condition that if a change in the coagulants used be deemed advisable by the Board, it should be made without unnecessary delay. The purification plant was built by the Norwood Engineering Company in 1901, and comprises 8 gravity

mechanical filters and appurtenances, contained in a reinforced concrete structure near the pump house. At the same time additions were made to the pump house to receive the new pumps then installed.

DESCRIPTION OF PLANT.

During the special investigagtion by the State Board of Health, the plant comprised the following features: 2 cast iron intakes, 2 low service pumps, 2 settling or coagulating basins, 8 gravity mechanical filters, a clear well, 2 high service pumps, 2 steel tanks for storage purposes, and a distributing system. (See Plate XIV.)

Intake and Raw Water Pumps.

There are two cast iron intakes, one 16 inches in diameter, and one 18 inches in diameter, which extend into the river 250 feet beyond the low water line. These pipes rest on the bottom of the river, are protected by concrete, and terminate in two lengths of pipe, 7 feet long, in which are a large number of ⅝-inch holes on the down stream side. A great deal of trouble has been experienced from these intakes on account of their stoppage by leaves and other debris, particularly during the fall of the year.

From the intake, the water is pumped to the coagulating basins by two Lawrence vertical top centrifugal pumps of 5,000,000 gallons capacity each, connected to tandem compound condensing engines, which have a nominal speed of 290 R. P. M. A diaphragm is provided on the shaft, and it was thought that the water pressure acting on this would tend to neutralize the weight of the shaft, fly wheel and pump propellers, but it has not proven satisfactory on account of the great variation in the river level with consequent considerable variation in the upward pressure.

Coagulating System.

The coagulating system comprises a slaking tank for lime, a dissolving tank for copperas and four solution storage tanks.

Coagulants. The coagulants used are copperas and lime. The former is sugar copperas obtained from The American Steel & Wire Company. Until November, 1907, it has contained 1 per cent. of copper sulphate supposed to have a selective action, causing the removal of coli and similar germs. It is shipped in bags containing 200 pounds each. The lime is obtained from West Virginia, and is shipped in barrels, each containing 190 pounds.

Solution Tanks. The original tank for slaking lime was of reinforced concrete, and the lime was slacked with hot water. The temperature of the solution was so great that the tank cracked, and it was replaced with a wooden box, 7′ x 5′ x 1′ deep. From the slaking tank, the milk of lime flows by gravity into either of the solution tanks, where it is diluted to a weak milk of lime. The storage tanks for the lime are of reinforced concrete construction 6′ x 13′ x 20¾′, and contain agitators in the bottom driven by a gas engine. The capacity of each tank is 12,000 gallons.

The copperas is dissolved in a small reinforced concrete tank, from which the solution flows by gravity into the storage tanks which are 6′ x 6½′ x 20¾′, and have a capacity of 5,460 gallons each.

Means for Applying Coagulant. From the storage tanks the milk of lime is lifted by a small duplex pump to the head tank, and the excess quantity pumped flows back through an overflow into the solution tank. The amount of solution

used is very accurately regulated by means of an adjustable orifice in the head tank from which it flows by gravity and enters the raw water at the forebay.

Considerable difficulty has been experienced in obtaining a satisfactory method for introducing the solution of copperas. As originally installed, the solution was carried through a 3-inch lead pipe 200 feet long to a regulating tank in the raw water pump well, from which it flowed by gravity into the suction of the pumps. This pipe gradually filled with yellow scale, and was replaced with a 4-inch wrought iron pipe, which in turn was eaten by the solution, and it was found impossible to keep it tight, particularly at the joints. In the summer of 1907, the method of handling the copperas solution was changed, and by means of a water ejector the solution was pumped through a 1½-inch wrought iron pipe, and applied to the raw water force main, where it enters the coagulating basin. As the solution is diluted no trouble is experienced with the pipe beyond the ejector, but the suction is lead-lined and tends to clog. The ejector has not been satisfactory, as the quantity of solution pumped, other conditions being the same, is not so great when the solution tanks are empty as when they are full, causing unequal rates of application of the solution.

Coagulating Basins. The force main from the raw water pumps is carried through one of the coagulating basins and terminates in a forebay of 32,000 gallons capacity. The forebay contains a float valve, by means of which the depth of water in the basins is regulated. This float valve, however, has not proven satisfactory, and is not in use at the present time. From the forebay, the coagulated water passes into either one or both of the coagulating basins. These basins are approximately 24½ feet wide x 18 feet deep, and the length of the larger is about 75 feet, and of the smaller about 53 feet. The capacity of the larger basin is approximately 260,000 gallons, and of the smaller 180,000 gallons. At the ordinary rate of pumping, 1,700 gallons per minute, the period of coagulation in the two basins is 4.3 hours. Both compartments are well baffled every 12 feet, and the present average velocity of the water in the basins, when both are in operation, is theoretically 0.25 foot per minute.

The coagulated water flows through the basins and enters a concrete conduit, by which it is carried over the pipe gallery and discharged onto the filters.

Filters.*

Capacity. The filter plant comprises 8 gravity mechanical filters, each 20x10 feet, with a guaranteed daily capacity of 500,000 gallons, and a total capacity of 4,000,000 gallons, including wash water. The average rate of filtration for this capacity is approximately 109,000,000 gallons per acre per day.

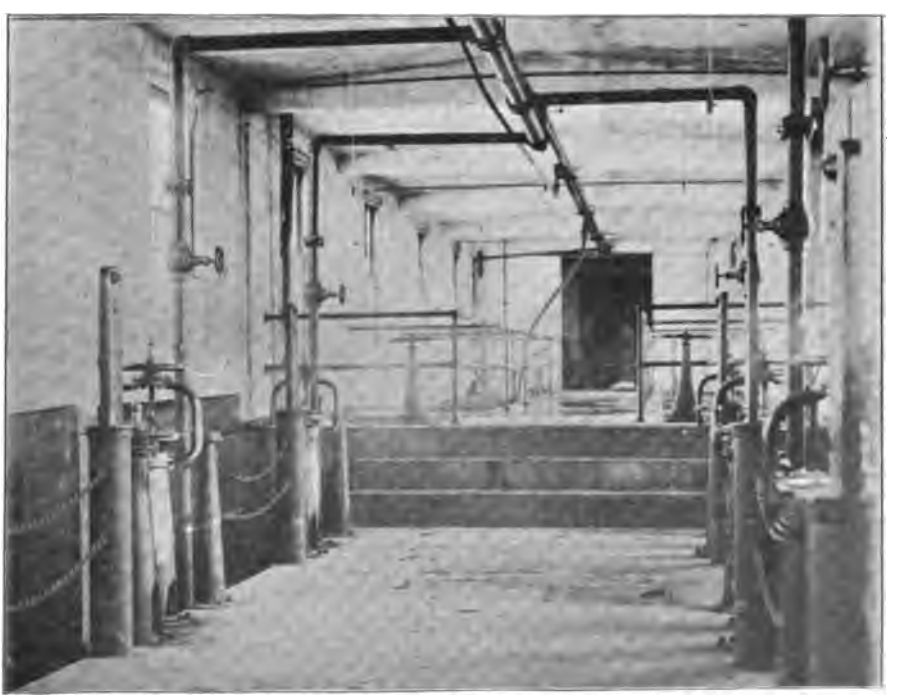
Strainer System. The strainer system comprises slotted brass tees, fitted at 6-inch intervals into 2-inch galvanized iron laterals. On each arm of the tees are 18 slots, approximately 0.3 c. m. long by 0.4 m. m. wide, symmetrically placed.

Filtering Material. On the strainer system there is placed a 9-inch layer of gravel, screened from 3/16-inch to ¼-inch in size. The filtering material consists of approximately 3 feet of sand, with an effective size of 0.46 m. m. and a uniformity coefficient of 1.4. The depth of filtering material has varied during the special investigation, as there is considerable waste of sand, which is carried into the gutters during washing. In the summer of 1907, one filter was emptied and the sand contained placed on top of the other seven filters. This filter was then refurnished with sand obtained from the Muskingum River, from which the coarse material was screened, and which has an effective size of 0.33 m. m. and a uniformity coefficient of 1.7. This sand has given very good satisfaction to date.

Washing System. The filters are washed by a reverse current of wash water, which is pumped from the clear well by a Lawrence centrifugal pump. The

*See Plate XV.

Marietta. — Interior of Coagulant Room.



Marietta. — Interior of Filter House.

capacity of this pump varies somewhat with the depth of water in the clear well, but the average quantity applied is such that the vertical rate of washing is about one foot per minute.

Air is used to assist in washing the filters, and is applied through 5/16-inch brass laterals 8 inches above the wrought iron laterals.

The gutters for the removal of the dirty wash water are built on the dividing walls between the filters, and are 16 inches wide by 16 inches deep. Wash boards are provided in order to prevent loss of sand during washing.

Automatic Devices. Each filter is equipped with an automatic rate controller of the Norwood type, which is submerged when the depth of water in the clear well is greater than 6 feet. By means of a valve stem the rate of filtration can be changed on the operating floor, and a disc is provided on each stem, showing the rate at which the filter operates. Loss of head gages are provided, but no record is kept of the loss of head on the filters.

Piping. It will be seen from the drawing, that the coagulated water is applied to the filter by means of a cast iron "spreader," and that no central gutter is provided. This is an important feature, as but 14 inches of water is generally carried on the filters, and at times there is a considerable disturbance caused by the influent, particularly in the front of the filter. The filter effluent and wash water pipes are 8-inch cast iron, and the drain is a 10-inch cast iron pipe.

Storage of Filtered Water.

Clear Well. The clear well is contained within the filter building, beneath the filters. It is approximately 44 feet wide by 49 feet long, with an available depth of 12.5 feet, and has a capacity of 200,000 gallons. At the ordinary rate of pumping, 1,700 gallons per minute, the length of the storage period in the clear well is 2.0 hours.

High Service Pumps and Distribution Reservoir. From the clear well, the filtered water is pumped to the storage tanks either by a D'Auria pump of 4,000,000 gallons capacity, or by a cross-compound crank and fly wheel Snyder-Hughes pump of 3,500,000 gallons capacity. There are two force mains provided, one 20 inches and one 12 inches, each 4,775 feet long, and which are continued from the center of the town to the reservoir by two 12-inch mains, each 2,500 feet long. The average pressure at the pumps is about 90 pounds.

For equalizing the supply, and also for fire protection, two steel storage tanks were built on Gross' Hill, 1¼ miles back of the river, about 206 feet above the pump room floor. These tanks are each 66 feet in diameter and 30 feet high, and have a total storage capacity of 1,500,000 gallons.

EXAMINATIONS.

During the special investigation by the State Board of Health, the water purification plant at Marietta has been visited seven times; on May (17-18), August (1-3), November (14-17), 1906, January (14-17), May (1-6), July (9-13), and October 7th, 1907. Regular examinations were made except on the visits of May 17th, 1906, and October 7th, 1907, when the plant was inspected.

OPERATION.

In operating the Marietta plant the general method of procedure is to pump the raw water from the river into the forebay and to introduce the coagulant into the raw water force main just at the point of discharge into the forebay. From the forebay, part of the water flows by gravity through the large settling basin and part through the smaller, and the discharge from both is conducted

through a concrete conduit to the filters. The water flows by gravity through the filters into the clear well, from which it is pumped to the storage tanks provided for the equalization of the consumption.

For the operation of the plant three engineers are employed, who are on service during approximately 8 hour shifts, and two filter attendants who have 12 hour shifts. During the greater part of the investigation it has been the custom to shut down the plant twice a day for periods of two hours, in order to give the engineers and attendants an opportunity to go home for their meals, so that the average period of operation of the plant has been approximately 18 hours. The character of the raw and filtered water is determined daily by a chemist, who also makes various necessary recommendations in regard to the quantity of coagulant to be used, and other incidental features of operation. The results of these analyses, expressed in monthly averages of his daily determinations, are shown in Table No. 33.

Average Daily Consumption.

As the average daily consumption has been very nearly constant during the year, these figures are not shown on the daily records. The total quantity of water pumped during 1906 was 880,500,000 gallons, which gives an average daily consumption of 2,410,000 gallons. The quantity of water used to wash the filters is not included in the above figure, and as it averaged about 7.4 per cent. of the quantity pumped, the total number of gallons filtered is 2,600,000. During 1907, the average daily consumption, not including wash water, was 2,269,000 gallons. Although the city of Marietta has recently entered into a contract to supply the the village of Williamstown, W. Va., with water, from the above figures it is apparent that there has been no increase in the average daily consumption during the last two years.

Application of Lime.

On the examination of August (1-3), 1906, the routine procedure for preparing the milk of lime used at Marietta was as follows: Into the slaking tank containing approximately 250 gallons of water heated to a temperature of 75 to 80 degrees C., there were placed 280 pounds of unslaked lime. The mixture was stirred thoroughly for 10 minutes, during which period the solution was raised practically to the boiling point. This strong milk of lime was then discharged into one of the lime storage tanks, which are used alternately, and where the strong lime water is diluted to 12,000 gallons. The mechanical agitators in the bottom of each lime solution tank are operated continuously when the tanks are in service, and their efficiency, as shown by the variations in the strength of the lime solution, has been determined during each examination.

From the storage tanks the dilated milk of lime is pumped to a head tank attached to the ceiling of the coagulant room, and flows by gravity through the solution pipes into the forebay. It is generally the custom to use practically the same quantity of lime for each charge and to vary its application by changing the quantity of solution, which is very accurately adjusted in the head tank.

Application of Copperas.

To prepare the iron solution the charges of sugar copperas, varying from 130 up to 1,720 pounds, are introduced into the small dissolving tank containing about 700 gallons of water. Water is passed through this tank into the storage tank below, and by the time the large tank is full the coagulant is entirely in solution. As previously noted, several methods have been tried for introducing the copperas solution into the raw water. These have been necessary on account

of the trouble experienced both from the clogging of the pipes and from leakage due to the acid reaction of the solution. At the time of writing this report, the method in use is to pump the solution by a water ejector through a 1¼-inch wrought iron pipe and force it into the discharge from the raw water pump near where it enters the forebay. It has been found necessary to use brass valves and connections in all the coagulant pipes, as the acid action of the solution is greatest at the joints.

During the several examinations following that of August 1st, 1906, the methods of preparing and applying the coagulant solutions has been practically the same as that described. Since recommended during these investigations, it has been the custom to maintain a slight phenol alkalinity in the filtered water, and when this condition is maintained, the ratio of the lime required to the copperas is such that practically 0.4 grain of lime is applied for each grain of copperas used.

Quantity of Coagulant Used.

The method generally employed to coagulate the water is to introduce such a quantity of copperas as is deemed necessary and then to so adjust the quantity of lime used that there results a slight red color in the water at the forebay when tested with phenolphthalein. The average quantity of copperas necessary during the years 1906 and 1907, has been 2.2 grains per gallon, and has required 0.77 grain of lime for its precipitation. The maximum quantity of copperas used as noted in the daily records is 6.7 grains per gallon on Jan. 15, 1907, during which time the river had a turbidity of 1500 parts per million. The quantity of lime used at this time was 1.3 grains per gallon.

When the plant was first started in service, it was recommended by those who were introducing the lime and iron process that lime should be used in such quantities as to give from 10 to 20 parts of phenol alkalinity in the filtered water. After the plant had been operated in this manner for several months, it was found that the air pipes were clogged, and subsequently it was necessary to remove all the air pipes and clean them. It was learned that a considerable deposit of white incrustants of lime had formed on the inside of the air pipes, due to the use of too large quantities of lime.

In order to avoid a recurrence of this trouble, when the plant was again started in service the lime was used in such quantities as to give a neutral water in the forebay, and there frequently resulted a filtered water containing slight quantities of acid iron salts. The effect of the use of too small a quantity of lime is apparent in the results shown in the daily records, and will be discussed under "Efficiency of Coagulating Basin."

Coagulating Basins.

The use of the coagulating basins requires little discussion, although in the absence of automatic control some difficulty is experienced in maintaining the proper height of water in the basins and on the filters. The float valve provided on the raw water main in the forebay has not proven satisfactory, as it occasionally sticks, and its use has been discontinued. It is necessary in order to maintain the proper depth of water on the filters that the raw water pumps and filters shall discharge the same quantities of water, and occasionally, when the pumps are operated too slow, there results a decreased depth of water on the sand in the filters.

In general it may be said that in the absence of other preliminary treatment it is necessary to carefully watch the results obtained by the coagulating basins, as the work done by them is one of the principal factors in determining the efficiency of the plant.

Filters.

Rate of Filtration. Although the filters are provided with rate controllers intended to maintain their operation at equal rates, it has not been the custom to operate the Marietta filters in this manner. From the fact that the controllers are governed by gate stems operated from the main floor of the filter house, it is very easy to change the rate of filtration. But little attention is paid to maintaining the filtered water pump at a constant rate, so that there are considerable variations in the draft on the clear well, which require corresponding changes in the quantities of water filtered. In order to meet these changes it is the custom to vary the rates of the different filters from time to time. In other words, the method of operating the plant is to keep all of the filters in constant service, except during such times as some of the units are washed, and to meet the variations in the quantity pumped from the clear well by changing the rates at which some of the filter units are operated.

There is a difference of opinion among operators as to whether it is better to operate the plant in this manner or to maintain a constant rate of filtration by the different filters, and to vary the total quantity filtered by changing the number of units in service. This point has not been investigated at Marietta, but it is doubtless true that better results would be accomplished if the controllers were not used as gate valves.

During the examinations, numerous measurements of the actual rate of filtration have been obtained. It has been found that, other conditions being the same, there is a greater discharge by the controllers when they are submerged than when flowing free. During one examination, the average rate of filtration was 17 per cent. greater when there were 10 feet of water in the clear well than at a short time previous when there were but 5 feet of water in the clear well. It has also been found that, towards the end of the run, the rate of filtration is considerably less than at the beginning. This, however, is probably not due to the poor efficiency of the rate controller, but to the fact that the filters are operated too long between washings.

From the several measurements of the rates of filtration, and also from the average quantity of filtered water pumped, it has been determined that the average rate of filtration is about 80 million gallons per acre per day.

Washing. Although loss of head gages are provided, they have not been used to indicate when the filters need washing, but it has been the custom to clean the filters at regular intervals, generally once during 24 hours. During practically all of the examinations, four filters have been washed every morning and four in the afternoon.

A wash water pump is provided to furnish water at the rate of 12 inches per minute. There is, however, a slight variation in the rate of application of the wash water with the speed at which the pump is operated, and also with different depths of water in the clear well. In order to maintain the desired rate, 12 inches rise per minute, it is necessary to maintain a pressure at the pump of 6½ pounds per square inch.

The method of washing the filters that was in use at Marietta until May, 1907, was as follows: The filter was first drained until about 6 inches of water remained above the sand, and then air was turned on under about 5 pounds pressure and applied for 3 minutes. When the coagulated mat on the surface of the filter had been thoroughly loosened, wash water was turned on from below and its application, together with that of the air, continued for 15 minutes. The air and water were then shut off and the filter was ready for service. About 13.8 vertical feet of wash water are necessary to clean a filter, which quantity is unusually high and is probably due to the use of copperas

as a coagulant and to the fact that the length of time between washings is so great that the filtering material is compacted and requires considerably more agitation and scouring than would be the case if the filters were washed more frequently.

On the examination of May (1-6), 1907, it was found that the sand in the filters was not cleaned and that it contained numerous hard spots, which frequently extended from the surface of the sand down to the underdrain. These hard spots were particularly noticeable in front of the cast iron spreaders used to apply the coagulated water. At this examination it was suggested that the methods of washing the filters be changed, and that they be cleaned in the same manner as had been successfully used at Youngstown. This method is as follows:

First, drain the filter entirely and turn on air from below; when this is well distributed turn on coagulated water over the top of the sand until it stands within a few inches of the top of the gutter; continue the application of the air until the surface layer of the sand has been thoroughly scoured, which generally requires 3 or 4 minutes, and after which time it is found that the greater part of the deposited coagulant is contained in suspension in the water on the sand. The remainder of the washing is continued in the usual manner by applying the wash water from below until the sand is cleaned. The great advantage of this method of washing is that it gives a much better distribution of the air, which distribution takes place much more readily in the sand when dry than when full of water. It is probable that the water applied over the surface does not extend completely through the sand, but that there is an air pocket in the bottom of the filter.

This method of washing also permits a better inspection of the distribution obtained in the filter, and any hard spots in the sand are readily noticeable by the lack of agitation. It was recommended at this examination that these hard spots could be removed by working over the sand with a bar. Since May 1st, 1907, the filters have been washed in this manner, which is found more efficient than that formerly used.

A record has been kept of the number of filters washed during 1907 from February 1st to October 31st, and is shown in the following table:

March	188
April	212
May	240
June	212
July	222
August	242
September	224
October	240
Total washes in 215 days	1,780

From this table it will be seen that the average number of washings per day is 8.3, and as the average rate of application is 11 inches per minute for 15 minutes, or 20,600 gallons, the average daily quantity of wash water is 171,000 gallons. As the average daily consumption during this period was 2,300,000 gallons, the average quantity of water used to wash the filters during 1907 was 7.4 per cent.

This quantity of wash water is unusually high and is due in part to the custom of operating the filters too long between washing and also to the fact that there are not a sufficient number of gutters provided. The filters are 10 feet wide, and it is thus necessary for the wash water to travel 5 feet horizontally,

a distance greater than should be allowed, to obtain the most economical results. During the first examination at the plant it was recommended that the cast iron spreaders used to introduce the applied water be removed, and that a central gutter be provided. This would not only give a better distribution of the applied water, but would also carry away the dirty wash water more readily, and result in the use of less wash water.

CHARACTER OF RAW WATER.

Before discussing the results that have been obtained by the Marietta plant, it is necessary first to understand the character of the water that is treated. During each of the examinations, samples of the water as taken into the plant have been obtained from a small sample pump in the well containing the raw water pumps. As the river water has shown great variations at the different examinations, they will be discussed in turn.

EXAMINATION OF AUGUST (1-3), 1906.

The examination of August (1-3), 1906, followed a period of continued fair weather, and the river was clearing up as indicated by the decrease in turbidity and bacterial content. The presence of coli was indicated by the tests, which, however, were only presumptive as no means were available for complete affirmative tests.

EXAMINATION OF NOVEMBER (14-15), 1906.

The examination of November 14th also followed a period of fair weather and the river was clearer than at any other time during the investigation. That it was clearing up is indicated by the decrease in the number of bacteria which continued until noon of November 15th. In the afternoon of November 15th, however, there occurred a sudden and remarkable increase in the bacterial content of the river as was indicated by the presence of but 650 per c. c. at 1:30 p. m. and 60,000 per c. c. at 11:00 p. m. No other change in the character of the raw water was detected, but as the river was very clear it was necessary to estimate its turbidity. These high numbers of bacteria continued until the afternoon of November 16th, and a decrease then followed during the examination. During the afternoon of November 15th, the larger settling basin was cleaned and it is apparent that the washings from this basin were discharged at such a point as to cause a contamination of the water at the intake. As the river was at but a 10-foot stage, the addition of such large quantities of foul deposit as was obtained from the bottom of the basins might have very great effect on the river water, and doubtless the changes that occurred were due to the flushing of the settling basin, which contained over three feet of deposit. This condition probably occurs whenever the settling basins are cleaned during low stages of the river, and would suggest the necessity for moving further down the river the drain by which the washings from the basins are discharged.

It should be noted that although the numbers of bacteria are unusually high, no coli were detected even in 100 c. c. portions of any of the samples taken.

EXAMINATION OF JANUARY (15-17), 1907.

The results of the examination of January (15-17), 1907, are of particular interest as the river was then in one of its extreme flood stages, such as occur generally at least once every year. The river was rising throughout the examination at the rate of approximately one inch per hour, and although the crest of the flood had not been reached at the conclusion of the examination, the river

had reached a 40-foot stage. The turbidity of the river and also its bacterial content reached a maximum on the first day of the examination, followed by a gradual decrease in the numbers of bacteria and a rapid decrease in the turbidity. This would indicate that the watershed of the river had been cleaned before the examination began. The alkalinity determinations indicate that the water was gradually becoming softer as the flow in the river increased, and at the crest of the flood the river had an alkalinity of but 12 parts per million. There was also a marked decrease in its dissolved color. No coli were found in any of the samples.

The evidence indicates, that, as would be expected during such very high stages in the river, it contained practically surface water entirely, and that the water-shed of the river is very rapidly cleaned out, resulting in a very soft, although dirty water.

Examination of May (1-6), 1907.

Fair weather prevailed at the beginning of the examination until May 4th, but early in the morning of the 4th there was a light rain, which was followed by a temporary increase in the bacterial content and turbidity of the raw water. The coli results during this examination are of particular interest, as they indicate a considerable temporary increase after the rain on the morning of the 4th.

Examination of July (9-13), 1907.

Fair weather prevailed at the beginning of this examination and the river was clearing up. On the night of July 11th, however, there was very heavy local showers and that this caused a very rapid change in the character of the river water is shown by the increase in turbidity to 2,800 parts per million and also by the increase in the number of bacteria contained. One of the most significant changes, however, was in the hardness. The alkalinity increased from 24 to 39 parts per million, which is contrary to what would have occurred if representative river samples had been obtained. The high color and increase in the hardness show that the water obtained at the Marietta intake consisted largely of the discharge from Duck Creek, which was running out. The crest of the rise in the river occurred at about 8:00 A. M. on July 12th, and was followed by a very rapid decrease first in the turbidity and then in the bacteria.

Quantitative determinations in the number of coli in the river were obtained during this examination, using dilutions with bile media. The results indicate the presence of at least two coli per c. c.

Evidence indicates that there is considerable local contamination of the Ohio River at the Marietta intake during such times as there is a high discharge from Duck Creek. This would be expected from the fact that the septic tank used to treat the sewage from the Washington County Infirmary does not cause any purification, and that considerable filth accumulates on the sides of the stream into which its effluent is discharged. During severe local rains these accumulations are washed into Duck Creek.

Inspection of October 7th, 1907.

Although no samples were taken during the inspection of October 7th, 1907, unusually interesting conditions prevailed at the plant as the river then contained very large quantities of dissolved color, which effected the ease with which the water was coagulated. Although comparatively clear, it was necessary to use nearly 3 grains of copperas per gallon to coagulate the water, and it is apparent that there is a chemical reaction between the coagulant and the dissolved color in the water, which tends to render the coagulant ineffective.

Daily Records.

The average conditions of the Ohio River at Marietta are shown in the daily records in Table No. 33. It will be seen that its average turbidity is about 400 parts per million, and that particularly during the fall season it contains considerable quantities of dissolved color. The average number of bacteria contained is about 8,000 per c. c. Chemically, it is shown to be much softer than is generally the case with other rivers in Ohio, and it is apparent that when the objectionable turbidity and bacteria are removed, there should result a filtered water that is very satisfactory for domestic use.

A review of the above discussion of the Ohio River at Marietta indicates that while the water has a very objectionable appearance, except under unusual conditions, its satisfactory purification requires merely the removal of suspended matters and dissolved color, as there are but few occasions showing evidence of serious pollution. Following local rains, however, especially during low stages of the river, there is a serious danger of pollution by Duck Creek. At such times the purification of the water requires extreme care in operation of the filter plant in order to produce a wholesome effluent.

It is apparent that the location of the intake of the Marietta waterworks could be changed to advantage, and that if it were moved to the other side of the river the local influence from Duck Creek would be largely avoided.

EFFICIENCIES.

Guarantee.

The contract with the filter company contains the following guarantees of the efficiency of the plant: "That the filtered water shall be odorless, colorless, bright and clear and free from suspended matter. It shall contain no more iron or aluminum sulphate than the raw water, no undecomposed coagulant nor free acid nor alkali. When the raw water contains 3,500 or more bacteria per c. c. there shall be a removal of 98 per cent. by the plant, and when the raw water contains less than 3,500 per c. c. the filtered water shall not contain more than 75 per c. c."

Intake.

Especially during the fall of the year, when the river water contains a great many leaves, considerable trouble is experienced from stoppage of the intake. At times it is necessary to shut down the pumps and to back-flush the intake from the coagulating basins every half hour during the day. This constant stopping of the plant makes it difficult to obtain a regular adjustment and application of the coagulants and also results in considerable waste of coagulated water used for flushing.

Methods of Applying Lime.

During each of the several examinations, samples of the milk of lime were obtained from the head tank in the preparation room at regular intervals of either one or two hours. These samples were titrated at the plant for available CaO. Results of the titrations, together with the length of the examination and the theoretical strength of the milk of lime are shown in Table No. 32. The theoretical strength is figured assuming that the lime contains 100 per cent. CaO. During the several examinations the average amount of lime available as CaO has been 72 per cent.

The table also contains the maximum and minimum strengths of the solution. The maximum strengths have been found when the solution tanks were full and the minimum when they were nearly empty. The considerable variations in the

strength of the milk of lime are due to incomplete washing out of the lime slaking box, variations in the percentage purity of the lime, the temperature of the water used, and inefficiencies in the method of agitating the solutions in the storage tanks. The latter are rectangular in section and doubtless much better results would obtain with the use of round storage tanks and weaker solutions.

TABLE NO. 32.

Marietta — Strength of Lime Solution.

Date.	Length of Exam.	Theor. Strength of Lime Sol'n.*	Act. Strength of Sol'n. Gr. p. Gal.			Act. Percent. CaO Available.
			Average.	Minimum.	Maximum.	
	Hours.	Gr. P. Gal.				
8–2–06	24	192	150	134	210	78
11–15–06	36	192	123	98	153	64
1–15–07	33	192	147	129	155	77
5–1–07	48	192	135	117	152	70
7–10–07	14	192	134	128	142	70
Average	31	192	138	121	162	72

* Assuming lime 100 per cent. CaO.

Application of Copperas

Samples of the copperas solution have been obtained from the regulating tank and from the top of the storage tank. There has been but little variation in the strength of the copperas solutions, which have remained practically constant during the running-off of a tank. The results are of particular interest, as they indicate that agitation of the copperas solution is not necessary. It has generally been found also that very nearly 100 per cent. of the copperas has been available.

Previous to November, 1907, the copperas used at Marietta has contained nominally one per cent. of copper sulphate. During the examination of July 9th, 1907, it was found that there was no apparent selective action by the coagulant in removal of coli, and it was then advised that the use of copper sulphate be discontinued. Since November, 1907, no copper has been contained in the coagulant.

Coagulating Basins.

The results obtained at Marietta as shown in the daily records illustrate the great importance of the work done by the coagulating basin and the effect of its various efficiencies on the final results obtained. The efficiency of bacterial removal has varied from 36 per cent. in September, 1906, to 94 per cent. in July, 1907. In September, 1906, an average quantity of 1.29 grains of copperas per gallon were used, and during Juy, 1907, 3.25 grains per gallon.

When the Marietta plant was first started in operation, there was little information at hand relative to the use of copperas and lime for coagulants, and it was advised by those most interested, that the best results required the application of greater quantities of lime than were necessary to neutralize the coagulant, which excess of lime would result in a slight softening of the treated water. This method of treatment was used, and resulted in clogging the filters, as has been previously described. In order to avoid "after deposits" of lime, the coagulants

were then so adjusted that the water at the forebay was neutral to phenolphthalein. This generally resulted in the filtered water containing small quantities of acid iron salts. During 1906, although mono carbonates were shown to be present in the filtered water during three months, the figures do not represent the general conditions, as during about 25 days of each of these months there was no phenol alkalinity in the filtered water. The average bacterial removal by the settling basins during 1906 was 63.8 per cent.

During the examination of May 1st, 1907, the necessity for maintaining small quantities of mono carbonates in the filtered water was advised, and since that time greater attention has been paid to the adjustment of the coagulants, and the use of lime has been increased, so that there has resulted about 5 parts per million of mono carbonates in the filtered water. There has resulted a striking increase of the bacterial removal by the basins, which increase is undoubtedly due to better coagulation with the freer use of lime. From February, 1906, to May, 1907, the average removal by the basins was 64 per cent., while from May to November, 1907, their removal was 86 per cent. This shows an increase in removal of 22 per cent. Since May, 1907, the average bacterial removal by the plant has been increased to 98 per cent., due in part to better conditions in the filters, but principally to the improved efficiency of the basins.

In general it may be said that, in order to obtain the most economical and efficient results, it is necessary that the turbidity of the water in the river be reduced to about 45 parts per million in the water applied to the filters. From the fact that the river is frequently very turbid this reduction in turbidity occasionally requires the use of very large quantities of coagulant. No records of the turbidity of the applied water were kept at Marietta until September, 1907, when it was advised that these records were of great value, and since which time they have been kept. The average, maximum and minimum turbidities of the applied water during September, October and November, 1907, are shown as follows:

	Average.	Maximum.	Minimum.
September	29	55	12
October	19	50	13
November	29	75	13

The average bacterial removal during these three months has been 84 per cent. These results indicate very satisfactory work by the basin.

Filters.

The efficiency of removal by the plant has varied greatly, although the average removal for both 1906 and 1907 has been 95 per cent. This figure is considerably below the average removal guaranteed for the plant. The least removal was in February, 1907, and was but 72.5 per cent. A gradual decrease in the efficiency of the plant was noted during the first part of 1907, and it was suggested by a representative of the contractors who built the plant that the poor removal was due to the occasional shutting down of the plant, and the deposition of all of the coagulated masses in the basins. This point was investigated, and it was found that even better results obtained when the plant is first started in operation after standing idle, if not for too long periods. If, however, the filters are operating under a negative head, it is necessary to wash them after shutting down, as the air which they contain is liberated, and breaks the mat on their surface.

On the examination of May 1st, 1907, it was found that the sand in the filters was not clean, due to inefficient washing as described. During and subsequent to this examination, a new method of washing was used, and that the

poor removal by the filters was due to the inefficient washing was shown both by the general improvement in the bacterial results obtained, and also by the fact that when the new method of washing was first tried, greater numbers of bacteria appeared in the effluent than in the applied water.

There are several features that tend to cause poor results by the filters, among which may be mentioned the insufficient depth of water maintained on the sand, a fact, which, together with the poor method of application of the coagulated water, frequently results in a disturbance of the sand, particularly in the front of the filters. It is also the custom to operate the filters too long a time between washing. After the plant is shut down, frequently the filters are started in service without preliminary washing, which is done at regular intervals, and not when necessary.

That the efficiency of the filters is largely determined by the degree of bacterial removal by the coagulating basins, is clearly indicated in the results obtained since May, 1907, since which time there has been a removal by the filters of 98 per cent., and a removal by the basins of 86 per cent.

REVIEW OF EFFICIENCY OF PLANT DURING SPECIAL INVESTIGATION.

Although in general it may be said that the water supply of Marietta is wholesome, as is indicated by the absence of typhoid among the consumers, yet there are several features that tend to decrease the efficiency of the plant, as follows:

Better results would undoubtedly be obtained if the intake were moved into deeper water on the West Virginia side of the Ohio River, a change which would eliminate the pollution by Duck Creek.

Most of the trouble that has been experienced in the handling of the coagulants has arisen from the acid character of the copperas solution, and also from the fact that deposits have been formed in the copperas pipes. The evidence indicates that the proper application of copperas requires that its solution be carried in brass pipes, and that the best method for its application is similar to that in use for the lime, a method with which no difficulty has been experienced, and which permits an easy regulation of the rate of application.

It is apparent that the use of copperas and lime as coagulants requires an accurate adjustment between the two, so that there results a filtered water containing a small, and only a small, quantity of mono carbonates. The absence of mono carbonates results in a poor coagulation, while if too great a quantity of lime is used "after deposits" are formed in the filters.

It will be seen from the daily records that the use of copperas and lime as coagulants results in an increase of total hardness in the treated water of approximately one-half grain per gallon for each grain per gallon of copperas used. The average removal of color has been satisfactory, but occasionally considerable quantities of dissolved color have been found in the filtered water, especially during the fall of the year.

Better results might be obtained from the filters if a central gutter were provided, which would permit a better application of the applied water, and would also give a more efficient removal of the wash water. Most of the trouble that has been experienced in the operation of the filters has been due to poor washing, and has been largely eliminated by the use of an improved method of washing.

It will be remembered that the use of copperas and lime as coagulants at Marietta was not unconditionally approved by the State Board of Health. It is apparent that the only feature which recommends their use is their comparative less cost. The use of alum would result in the removal of several difficulties inherent with the present process, such as the accurate adjustment of the two

coagulants, and would also cause a more brilliant effluent from the filters and one frequently containing less dissolved color. It is probable also that the use of copperas and lime requires greater quantities of wash water than is necessary with alum, as the precipitate with the copperas is heavy and sticky, and more difficult of removal than the coagulated masses precipitated with alum.

In conclusion it should be stated that the filtration plant at Marietta has well fulfilled the purpose for which it was constructed, in that it has furnished a soft, clear, wholesome water, admirably suited for domestic uses. While some difficulties have been experienced in operating the plant they have been largely due to the use of a comparatively new process of coagulation not well understood. Several of these difficulties have developed during the investigation by the State Board of Health, and their removal has been accomplished by the co-operation of the Marietta officials with the Board, so that at present the plant is giving very satisfactory results.

COST OF INSTALLATION.

In the following table are shown the costs of the improvements added in 1901, which table does not include any of the costs of installation previous to that time:

Filter house	$30,000
Includes clear well, filters, coagulating basins, apparatus for applying coagulant, chemical storage room and wash water and blower.	
D'Auria high duty pump	13,000
Two raw water pumps	10,000
Pump connections to filter house and additions to pump house	16,750
Total cost of installation	$69,750

COST OF OPERATION — 1906.

Labor		$4,260 00
3 engineers	$2,460 00	
2 attendants	1,200 00	
Analyst	600 00	
Coagulants*		1,752 02
Copperas	1,452 07	
Lime	299 95	
Fuel		3,616 83
Gas for boilers, $0.072 per M ft.	3,509 21	
Gas for agitators	107 62	
Incidentals		223 00
Oil	116 00	
Waste	12 00	
Laboratory supplies	10 00	
Ice	15 00	
Extras	70 00	
Total cost of operation		$9,851 85

Total water consumption, 1906		880,502,000
Average cost per million gallons		$11 18
Includes labor per million gallons	$4 83	
Coagulants* per million gallons	1 98	
Fuel per million gallons	4 10	
Incidentals per million gallons	25	

*Includes cost of coagulants purchased during 1906; for cost of coagulants actually used see daily records in Table No. 33.

TABLE NO. 33.

Marietta — Record of Operation, 1906-7.

Month.	Coagulants Gr. per Gal.		Cost of Coagulants per Mil. Gals.	Parts Per Million. River Water.								Parts Per Million. Filtered Water.							Bacteria Per C. C.			Efficiencies.	
	Copperas.	Lime.		Turb.	Color.	Alk.	Incrust.	Tot. Hard.	Calcium.	Iron.	Free CO_2	Color.	Mono. Carb.	Tot. Alk.	Incrust.	Tot. Hard.	Calcium.	Iron.	River Water.	Outlet of Basins	Filtered Water.	Basins.	Filters.
1906.																							
February	.....	.....	.....	77	.....	21	.....	.....	.....	.45	.....	9	0.	27	.....	.....	.....	.02	6,100	2,800	338	54.3	94.5
March	2.42	.71	2.39	510	.....	23	.....	.....	.....	.67	3.5	9	0.	25	.....	.....	.....	.02	15,400	7,560	2,400	50.6	84.4
April	2.34	.75	2.35	410	.....	18	.....	.....	.....	.41	2.9	12	0.	20	.....	.....	.....	.03	12,500	5,300	875	57.2	93.0
May	2.16	.64	2.13	310	.....	27	.....	.....	.....	.59	2.3	10	0.	26	.....	.....	.....	.03	2,450	625	63	74.	97.0
June	2.08	.66	2.10	640	.....	27	.....	.....	.....	.37	.....	10	2.	29	.....	.....	.....	.03	14,000	375	77	73.2	99.4
July	2.28	.61	2.10	1,450	.....	36	50	95	38	.23	.....	10	0.	37	74	111	40	.02	3,590	425	93	87.9	97.2
August	2.77	.70	2.65	925	.....	26	49	75	26	1.00	.....	8	0.	29	63	92	32	.12	4,600	250	39	45.9	99.2
September	1.29	.40	1.28	71	.....	26	63	88	30	.66	.....	6	0.	27	72	99	34	.24	450	290	35	35.6	92.2
October	1.75	.57	1.77	92	.....	28	38	66	24	.85	.....	14	0.	31	50	81	30	.31	1,300	275	47	78.9	96.4
November	1.97	.69	2.02	300	.....	27	26	53	18	1.23	.....	12	2.	30	38	68	26	.38	10,500	4,500	475	57.2	95.5
December	2.27	.75	2.29	320	.....	22	23	45	15	.41	.....	8	4.	25	37	62	24	.20	19,500	6,550	850	87.1	95.7
Average	2.13	.65	2.10	464	.....	25	43	70	25	.62	2.9	10	0.7	28	56	86	31	.13	8,200	2,623	481	63.8	94.9
1907.											Ave. about 3 pts. p. mil.												
January	3.09	.80	2.97	408	9	16	27	43	15	.....		7	2.	19	44	64	24	.....	20,500	4,300	800	78.8	96.1
February	1.66	.60	1.72	110	3	18	47	65	21	0.08		5	5.	25	52	77	27	.05	4,000	1,700	1,100	58.5	72.5
March	3.38	.95	3.30	300	6	17	33	50	.....	.....		8	0.	21	42	63	.....	.....	6,800	3,400	500	50.	92.7
April	1.17	.82	1.47	175	6	18	35	53	18	.05		6	0.	20	46	66	23	.08	4,600	1,500	200	67.4	95.6
May	2.06	.83	2.18	220	10	22	21	43	15	.11		6	3.8	27	34	61	20	.06	3,900	475	45	87.8	98.8
June	2.04	.85	2.16	170	13	25	19	44	15	.11		15	6.	30	32	62	24	.11	3,500	680	49	80.6	98.9
July	3.25	1.23	3.38	1,500	18	30	20	50	21	.10		15	5.	33	42	75	31	.09	15,000	850	170	94.4	98.9
August	1.66	.67	1.76	250	10	28	43	71	27	.06		8	6.	31	55	86	34	.05	2,300	350	50	84.8	97.8
September	2.46	1.15	2.71	330	10	28	33	61	26	.04		9	8.	30	52	82	34	.35	5,300	650	141	87.8	97.3
October	1.68	.85	1.90	80	55	21	41	62	21	.....		14	3.4	27	54	81	28	.17	4,100	725	150	82.5	96.3
November	2.35	1.05	2.56	135	19	17	32	49	15	.22		10	6.	24	44	68	25	.15	10,800	2,100	301	81.5	97.2
Average	2.24	.89	2.37	334	14	22	32	54	19	.09	.....	8.6	4.	26	45	71	27	.12	7,350	1,520	319	77.6	94.7

Average efficiency of filters from May 1 to Nov. 30, 1907 = 97.9%. Filtered water is always clear (Turb. = O+).

TABLE NO. 34.

Marietta — Results of Analyses During Examinations.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	
	1906	A. M.								
292	8-1	10:00	Raw water	4,100	+	+				
		P. M.								
295	8-1	2:00	Raw water	1,600						
297	8-1	2:30	Raw water	1,700				170	20	
298	8-1	5:00	Raw water	1,200						
300	8-1	6:00	Raw water	1,600						
302	8-1	9:00	Raw water	4,400						
293	8-1	10:00	Set. water top No. 7	375	0					
		A. M.								
294	8-1	10:00	Clear well	28	0					
		P. M.								
296	8-1	2:00	Filtered water at pump	37			2	0	31	
299	8-1	5:00	Filtered water at pump	31						
301	8-1	6:00	Filtered water at pump	140						
303	8-1	9:00	Filtered water at pump	39						
		A. M.								
304	8-2	12:30	Raw water	1,300						
306	8-2	3:00	Raw water	1,100						
308	8-2	6:30	Raw water	1,300						
318	8-2	10:30	Raw water	2,100						
		P. M.								
321	8-2	2:00	Raw water	1,500						
324	8-2	2:30	Raw water	350						
333	8-2	5:00	Raw water	1,100						
336	8-2	9:00	Raw water	2,300						
		A. M.								
319	8-2	10:30	Settling basin at outlet	130						
		P. M.								
322	8-2	2:00	Settling basin at outlet	300						
334	8-2	5:30	Settling basin at outlet	140						
	1906	A. M.								
305	8-2	12:30	Filtered water at pump	15						
307	8-2	3:00	Filtered water at pump	26						
309	8-2	6:30	Filtered water at pump	85						
320	8-2	10:30	Filtered water at pump	120						
		P. M.								
323	8-2	2:00	Filtered water at pump	14						
335	8-2	5:30	Filtered water at pump	8						
337	8-2	9:00	Filtered water at pump	100						
		A. M.								
310	8-2	10:00	Effluent No. 1	150						
311	8-2	10:00	Effluent No. 2	16						
312	8-2	10:00	Effluent No. 3	12						
313	8-2	10:00	Effluent No. 4	10						
314	8-2	10:00	Effluent No. 5	65						
315	8-2	10:00	Effluent No. 6	55						
316	8-2	10:00	Effluent No. 7	4						
317	8-2	10:00	Effluent No. 8	10						
		P. M.								
325	8-2	4:00	Effluent No. 1	27						
326	8-2	4:00	Effluent No. 2	12						
327	8-2	4:00	Effluent No. 3	15						
328	8-2	4:00	Effluent No. 4	6						
329	8-2	4:00	Effluent No. 5	2						
330	8-2	4:00	Effluent No. 6	6						
331	8-2	4:00	Effluent No. 7	4						
332	8-2	4:00	Effluent No. 8	6						
			Average	25						

NOTE — Aug. (1-3) 1906, used 2.9 grains of copperas per gallon and 1.6 grains of lime per gallon.

TABLE NO. 34 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Phen. Alk.
		A. M.								
338	8-3	12:30	Raw water	450	.....	.....	.....	.....	.....	.....
340	8-3	4:30	Raw water	450	+	+	.....	.....	.....	.....
339	8-3	12:30	Filtered water at pump	65	.....	.....	.....	.....	.....	.....
341	8-3	4:30	Filtered water at pump	38	0	.....	.....	.....	.....	.....
	1906	P. M.								
771	11-14	1:30	Raw water	18,400	0	0	15	30±	27	—4.0
774	11-14	11:00	Raw water	3,300	.....	.....	38	30±	27.5	—3.5
			Average	7,200	.....	.....	27	30±	27	.....
773	11-14	2:15	Set. water from conduit	24,000	.....	.....	.....	.....	38	0
775	11-14	11:00	Set. water from basin	725	.....	.....	.....	.....	31	—1.5
772	11-14	2:00	Filtered water, tap in laboratory	1,400	0	0	10	<5	29	4.0
776	11-14	11:00	Filtered water, engine room.	375	.....	.....	10	<5	28.5	—1.5
		A. M.								
778	11-15	8:30	Raw water	1,000	.....	.....	35	30±	30	—2
		P. M.								
783	11-15	1:30	Raw water	650	0	0	35	30±	30	—3.0
787	11-15	11:00	Raw water	60,000	.....	.....	25	30±	26	—5.0
		A. M.								
779	11-15	8:30	Set. water conduit	950	.....	.....	.....	.....	30	—3.0
		P. M.								
784	11-15	1:30	Set. water conduit	900	.....	.....	.....	.....	28	—3.0
788	11-15	11:00	Set. water conduit	37,000	.....	.....	.....	.....	29	—4.0
		A. M.								
780	11-15	8:30	Filtered water, engine room.	95	.....	.....	10	<5	30.5	0.5
781	11-15	10:30	Filtered water, clear well	46	.....	.....	10	<5	30	—2.0
		P. M.								
785	11-15	1:30	Filtered water, engine room.	10	0	0	10	<5	29	—2.5
786	11-15	5:00	Filtered water, engine room.	1,900	0	0	7	<5	26	—3.0
789	11-15	11:00	Filtered water, engine room.	2,900	0	0	7	<5	26	—4.0
		A. M.								
777	11-15	6:30	Tap at Norwood hotel	31	0	0	8	25	29	0
		P. M.								
782	11-15	12:30	Tap at Norwood hotel	23	0	0	10	<5	29	—3.0
		A. M.								
791	11-16	7:30	Raw water	48,000	0	0	25	30±	25	—3.5
		P. M.								
797	11-16	3:30	Raw water	65,000	0	0	.....	30±	25	—4.0
800	11-16	11:00	Raw water	45,000	0	0	15	30±	26	—5.5
			Average	53,000	.....	.....	20	30±	25	—4.3
		A. M.								
792	11-16	7:30	Set. water, conduit	47,000	.....	.....	.....	.....	28	—2.0
795	11-16	11:00	Set. water, conduit	34,000	.....	0	.....	.....	27	—2.0
		P. M.								
798	11-16	4:00	Set. water, conduit	18,000	.....	.....	.....	.....	27	—2.0
801	11-16	11:00	Set. water, conduit	18,000	.....	.....	.....	.....	26	.....
			Average	29,000	.....	.....	.....	.....	27	.....
		A. M.								
793	11-16	7:30	Filtered water, engine room.	3,500	0	0	7	<5	27	—2.0
794	11-16	11:00	Filtered water, engine room.	4,800	0	0	10	<5	27	—2.0

TABLE NO. 34 — Continued.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Phen. Alk.
		P. M.								
799	11-16	4:00	Filtered water, clear well....	3,600	.....	.....	10	<5	28	—2.0
802	11-16	11:00	Filtered water, pump.....	2,000	0	0	10	<5	27	—2.0
			Average	3,475	0	0	9	<5	27	—2.0
796	11-16	1:00	Tap at Norwood hotel.....	2,700	0	0	10	<5	28	—2.0
799	11-16	6:30	Tap at Norwood hotel.....	1,700	0	0	25	<5	28	—2.5
			Average	2,200	.....	.....	18	5	28	—2.
		A. M.								
804	11-17	8:30	Raw water	22,500	0	0	15	8±	25—	—3.5
805	11-17	8:30	Set. water, conduit.....	18,500	.....	.....	.....	.....	27	.....
806	11-17	8:30	Filtered water from pump..	1,600	0	0	10	<5	26	—2.5
808	11-17	7:00	Tap at Norwood hotel.....	.....	0	0	10	<5	26	—2.5

Incrustants, Samp. No. 804, 86; Samp. No. 806, 49.
Nov. (14–17) 1907, used approx. 2.0 grains of copperas per gallon.

TABLE NO. 34 — Continued.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	CO_2
	1907	A. M.								
929	1-15	8:00	Raw water[1]	36,000	.....	.....	20	1,500	18	4
		P. M.								
933	1-15	2:00	Raw water	41,000	.....	.....	20	900	17	3.5
937	1-15	8:00	Raw water	26,000	.....	.....	.....	700	.....	.....
		A. M.								
930	1-15	8:00	Set. water, top filter No. 7.	4,900	.....	.....	.....	.....	18	2
		P. M.								
934	1-15	2:00	Settled water, conduit.....	2,200	.....	.....	3	50	18	4.5
938	1-15	8:00	Settled water, conduit.....	1,400	.....	.....	.....	40	17	1.7
		A. M.								
931	1-15	8:00	Filtered water, clear well....	1,500	.....	.....	3	<5	21	0
		P. M.								
932	1-15	1:00	Tap at Bellevue hotel.....	500	0	0	5	<5	19	0.5
935	1-15	2:00	Tap in boiler room.....	550	.....	.....	3	<5	17	1.5
936	1-15	7:00	Tap at Bellevue hotel.....	600	.....	.....	5	<5	21	.....
939	1-15	8:00	Tap in boiler room.....	550	.....	.....	3	<5	17	1.5

Phen. Alk., Samp. No. 936, 1.0. Iron, Samp. 942, 0.60.
[1]River rising 1" per hour, 32' stage.
[2]River rising, at 34' stage; snowing.

TABLE NO. 34 — Continued.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	CO_2
940	1-16	A. M. 7:30	Raw water[3]	20,500	.....	.....	15	450	17	3.0
944	1-16	P. M. 2:00	Raw water	40,000	0	0	12	400	14	3.5
947	1-16	11:00	Raw water	29,000	0	0	10	425	13	3.0
941	1-16	A. M. 7:30	Set. water from conduit	3,900	.....	.....	8	30±	17	1.0
945	1-16	P. M. 2:00	Set. water from conduit	12,000	.....	.....	.....	50	17	1.0
948	1-16	11:00	Set. water from conduit	7,000	.....	.....	.....	40	15	1.0
942	1-16	A. M. 7:30	Tap in boiler room	1,000	0	0	5	<5	16	0
943	1-16	P. M. 1:00	Tap at Bellevue hotel	1,450	0	0	4	<5	17	1.0
946	1-16	2:00	Tap in boiler room	1,000	0	0	4	<5	17	0.5
949	1-16	11:00	Tap in boiler room	1,600	0	0	5	<5	15	1.0
951	1-17	A. M. 7:30	Raw water[3]	36,000	.....	.....	6	450	12	3.0
954	1-17	P. M. 2:00	Raw water[4]	21,000	0	0	8	325	13	3.0
952	1907 1-17	A. M. 7:30	Set. water from conduit	4,000	.....	.....	.....	45	12	2.0
955	1-17	P. M. 2:00	Set. water from conduit	5,800	0	0	.....	35	10	4.5
956	1-17	2:00	Tap in boiler room	1,100	0	0	3	<5	13	0.7
950	1-17	A. M. 7:00	Tap at Bellevue hotel	550	0	0	5	<5	18	0.5
953	1-17	7:30	Tap in boiler room	900	.....	.....	3	<5	14	0.5

[3]River rising ¾" per hour.
[4]River rising, 37' stage.
Jan. (15-17) 1907, used 6.7 grains of copperas per gallon and 1.3 grains of lime per gallon.

Field No.	Collected.		Source.	Bacteria Per C.C.	Colon in		Parts Per Million.				
	Date.	Hour.			1 C.C.	100 C.C.	Col.	Turb.	Alk.	CO_2	Phen Alk.
	1907	P. M.									
1283	5-3	5:00	Raw water	3,000	0	+	13	50	20	.....	.....
		A. M.									
1282	5-3	8:00	Clear well	425	0	0	6	5	21	1.5	.....
1283	5-3	9:00	Clear well	260	.....	.....	.....	.....	.....	.....	.....
		M.									
1284	5-3	12:00	Clear well	200	.....	.....	.....	.....	.....	.....	.....
		P. M.									
1285	5-3	1:00	Clear well	110	.....	.....	.....	.....	.....	.....	.....
1286	5-3	2:00	Clear well	175	.....	.....	.....	.....	.....	.....	.....
1287	5-3	3:00	Clear well	175	.....	.....	.....	.....	.....	.....	.....
			Average	225	.....	.....	6	5	21	1.5	.....
		A. M.									
1281	5-3	6:30	Tap at Bellevue hotel.	250	0	0	8	5	21	2.	.....
	1907	A. M.									
1291	5-4	8:30	Raw water	9,500	+	+	.....	70	18	3.	.....
		P. M.									
1296	5-4	1:00	Raw water	6,000	0	+	13	50	17	3	.....
			Average	7,800	.....	.....	13	60	18	3	.....
		A. M.									
1289	5-4	7:45	Clear water pump.....	110	0	0	6	5	26	.....	4.0
1292	5-4	8:45	Clear water pump.....	170	0	0	.....	5	.....	.....	.....
1293	5-4	9:45	Clear water pump.....	230	0	0	6	5	25	.....	4.0
1294	5-4	11:45	Clear water pump.....	210	0	0	4	5	23	.....	4.0
		P. M.									
1295	5-4	1:00	Clear water pump.....	160	0	0	4	5	25	.....	3.0
1298	5-4	2:00	Clear water pump.....	275	0	0	0	5	26	.....	5.0
			Average	190	.....	.....	4	5	25	.....	.....
		A. M.									
1290	5-4	7:45	Set. water from conduit	1,150	0	+	.....	22	26	.....	4.
		P. M.									
1297	5-4	1:00	Set. water from conduit	1,000	.....	.....	.....	24	27	.....	7.0
			Average	1,200	.....	.....	.....	24	27	.....	5.5

May (1-4) 1907, used 3.1 gr. of copperas p. gallon and 1.1 gr. of lime p. gallon.

TABLE NO. 34 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in .5 c.c.	Colon in 1 c.c.	Colon in 2 c.c.	Colon in 100 c.c.	Parts Per Million. Col.	Turb.	Alk.	Phen. Alk.
1	1907 7-10	A. M. 9:00	Raw water	5,000	+	+	+	....	18	275	24	1.5
6	7-10	P. M. 1:30	Raw water	5,300	+	+	+	....	18	275	24	.....
10	7-10	4:30	Raw water	4,100	+	+	+	....	15	240	25	.....
			Average	4,800	+	+	+	....	17	264	24	1.5
2	7-10	A. M. 9:00	Settled water from conduit	850	....	....	....	....	.....	35	30	9
7	7-10	P. M. 1:30	Settled water from conduit	1,200	....	....	....	....	.....	45	25	.....
11	7-10	4:30	Settled water from conduit	1,500	....	....	....	....	.....	.....	28	3
			Average	1,200	....	....	....	....	.....	40	28	6
3	7-10	A. M. 9:00	Effluent at pump	160	....	....	....	+	10	<5	24	2
4	7-10	11:00	Effluent at pump	70	....	....	....	+	10	<5	24	3
8	7-10	P. M. 1:30	Effluent at pump	50	....	....	....	+	10	<5	30	5
9	7-10	3:00	Effluent at pump	90	....	....	....	+	10	<5	30	4
12	7-10	4:30	Effluent at pump	190	....	....	....	+	10	<5	30	4
			Average	112	....	....	....	+	10	<5	28	4
5	7-10	1:00	Tap at Bellevue hotel.	43	....	....	....	+	10	<5	27	.....
14	7-11	A. M. 7:30	Raw water	8,900	+	+	+	....	39	900	28	.....
18	7-11	11:30	Raw water	18,000	+	+	+	....	80	1,200	29	.....
22	7-11	P. M. 3:30	Raw water	19,500	+	+	+	....	40	1,400	28	.....
			Average	15,500	....	....	....	....	80	1,167	28	.....
15	7-11	A. M. 7:30	Set. water from conduit	5,700	....	....	....	....	.....	150	27	.....
19	7-11	11:30	Set. water from conduit	1,400	....	....	....	....	.....	80	34	4
23	7-11	P. M. 3:30	Set. water from conduit	1,800	....	....	....	....	.....	35	38	9
			Average	3,000	....	....	....	....	.....	88	33	6.5
16	7-11	A. M. 7:30	Effluent at pump	575	....	....	....	+	18	<5	30	1.5
17	7-11	9:30	Effluent at pump	575	....	....	....	+	30	<5	29	1
20	7-11	11:30	Effluent at pump	400	....	....	....	+	17	<5	31	0.5
21	7-11	P. M. 2:00	Effluent at pump	350	....	....	....	+	15	<5	33	1.0
24	7-11	3:30	Effluent at pump	300	....	....	....	+	15	<5	33	1.5
25	7-11	5:00	Effluent at pump	190	....	....	....	+	15	<5	33	2
			Average	400	....	....	....	....	18	<5	32	1.5
13	1907 7-11	A. M. 6:30	Tap at Bellevue hotel.	32	....	....	....	+	10	<5	29	2
27	7-12	8:00	Raw water	24,500	+	+	+	....	38	2,800	39	.....
32	7-12	P. M. 2:00	Raw water[1]	24,500	+	+	+	....	40	1,800	38	.....
			Average	24,500	....	....	....	....	39	2,300	38	.....

[1] Incrustants 35 parts per million.

TABLE NO. 34 — Concluded.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in				Parts Per Million.			
	Date.	Hour.			.5 c.c.	1 c.c.	2 c.c.	100 c.c.	Col.	Turb.	Alk.	Phen. Alk.
28	7-12	A. M. 8:00	Settled water from conduit	420	....	....	....	....	.....	40	40	0.5
33	7-12	P. M. 2:00	Settled water from conduit	3,500	....	....	....	....	.....	75	48	5
			Average	2,000	....	....	....	....	.....	58	43	2.7
29	7-12	A. M. 8:00	Effluent at pump	275	....	....	....	+	15	<5	40	4
30	7-12	10:00	Effluent at pump	350	....	....	....	+	10	<5	40	3.5
31	7-12	M. 12:00	Effluent at pump	275	....	....	....	+	15	<5	40	4
34	7-11	P. M. 2:00	Effluent at pump[3]	525	....	....	....	+	10	<5	42	5
			Average	380	....	....	....	....	13	<5	41	4.1
26	7-12	A. M. 7:00	Tap at Bellevue hotel[3]	160	....	....	....	+	15	<5	37	5

[2]Incrustants — 46 parts per million.
[3]Incrustants — 65 parts per million.
July (10-12) 1907, used 4.8 grains of copperas per gallon and 2.4 grains of lime per gallon. CO_2, Samp. No. 6, 1.0; Samp. No. 10, 1.0; Samp. No. 7, 0.5; Samp. No. 5, 0.5; Samp. No. 14, 3.0; Samp. No. 18, 2.5; Samp. No. 22, 3.0; Samp. No. 15, 0.5; Samp. No. 27, 3.5; Samp. No. 32, 4.0.

NEWARK.

Newark, the county seat of Licking County, is situated in the central part of Ohio on the Licking River. It is one of the most thriving cities in the state and contains many manufacturing industries. The population has been steadily increasing and in 1906 was estimated at 18,000.

HISTORICAL.

Original Installation.

The waterworks were first installed by the Newark, Ohio, Water Company in 1886 in the northern part of the city on the bank of the north branch of Licking River, near the site of the present plant. The supply was taken from twenty-four, 4-inch Cooke driven wells, 32 feet deep, and two brick lined 20-foot wells, 21 feet deep, with gravel bottoms. The normal level of the ground water was about ten feet below the surface of the ground and was lowered five feet during pumping. The capacity of the wells gradually decreased, and it was finally found impossible to obtain a sufficient supply from them, so that in 1901 they were abandoned and a new supply taken from the Licking River.

Conditions Leading to Purification.

The watershed of the Licking River above the intake has an area of 230 square miles which consist in part of uninhabited woodland and in part of sparsely settled farm lands containing sixteen small communities with a total population in 1904 of about 5,300. There are no cities on the watershed, and the largest town is Utica which in 1904 had a population of 1,400. This village is but twelve miles above the intake of the Newark waterworks. All of these small communities are directy located on the banks of the river, and their surface drainage is directly washed into the stream. At Utica there are three sanitary sewers discharging into the river and also two slaughter houses so situated that in times of high water their refuse is washed into the stream.

Not only is there a considerable pollution of the water in the Licking River, but at times of heavy rains it carries large amounts of suspended matter which also make it unsuitable for domestic purposes without purification. When the new supply was taken from the river in 1901, it was necessary to install a purification plant which comprised mechanical filters without preliminary treatment of the water.

DESCRIPTION OF PLANT.

The new works comprise a filter house which is located about 50 feet east of the pump house and contains 4 mechanical gravity filters, together with solution tanks and appurtenances, built by the New York Continental Jewell Filtration Company; a new low service pump; a clear well which was formed by rebuilding one of the original wells; and a coagulating or sedimentation tank placed just south of the filter building. The filters are housed in a substantial brick building 42'x66', in which sufficient room is left for two new filter units when needed. (See Plate XVI.)

Intake and Raw Water Pump.

In order to insure a sufficient depth over the intake during low water stages of the river, a brush and stone dam was built which, when in repair, backs the water of the creek about 2 feet above its normal level. Very little sedimentation or purification is accomplished by the ponding above this dam. The intake consists of a crib formed by 2-inch planks 13 feet long, laid flat with their ends overlapping. The suction pipe enters the crib at one end in an open compartment 7 feet wide, while the opposite end of the crib contains rock filling of large stones. Openings two inches wide, or the thickness of the planks, are left in the sides while the top is sealed. The suction from the intake is a 20-inch cast iron pipe, about 200 feet long, which enters the filter building in the northwest corner and terminates in a forebay, 10 feet in diameter and 16 feet deep, the bottom of which is about two feet below extreme low water in the river. The suction of the raw water pump extends to about one foot above the bottom of the forebay and consists of a 10-inch cast iron pipe. The maximum suction lift to the pump is 18 feet, while the total lift from the extreme low water to the top of the settling basin is 32 feet.

The raw water pump is a 10-inch centrifugal pump built by the Morris Machine Works and has a nominal capacity of three million gallons per twenty-four hours.

Coagulating System.

Coagulant. The coagulant is obtained from the General Chemical Company of New York and is a standard brand of aluminum sulphate.

Newark. — General View of Plant.

Solution Tanks. The solution tanks for dissolving and storing the coagulant are of wood, two in number, each 6½′ in diameter by 8′ deep with a capacity of 1980 gallons. Only one of these tanks has been used during the special investigation.

Application. From the storage tanks, the alum solution is carried by a 1¼-inch wrought iron pipe to a small pump by which it is discharged into the force main near the raw water pump.

Coagulating Basin. The coagulating basin is an uncovered wooden tank just outside of the filter building. It has a diameter of 30 feet with a total depth of 24 feet (of which, however, but 23 feet are generally available), giving a capacity of 122,000 gallons, which, at the usual rate of pumping, 1370 gallons per minute, gives a coagulating period of one and one-half hours. As there are no baffles in the tank, the actual coagulating period is considerably less than the theoretical and is probably not greater than one hour. The tank is on a separate foundation and its top is 10 feet above that of the filters to which the water flows by gravity. Both the 12-inch cast iron inlet and the 16-inch cast iron outlet enter through the bottom, the former being carried two feet and the latter 20 feet into the tank.

Filters.

Capacity of Plant. The nominal capacity of the filter plant is two million gallons in twenty-four hours. It comprises four wooden tanks, each 15 feet in diameter with a combined area of 707 square feet, or 0.01625 acre.

Strainer System. The strainer system is similar to that in the Geneva filter, which has been described on Page 142.

Filtering Material. As originally installed the filters contained four feet of sand from Red Wing, Minn. It has been necessary to replenish the filtering material from time to time, which has been done with sand obtained from Sea Girt, N. J., at a cost of $5.00 per ton. The effective size of the sand in the filters, as determined in the fall of 1907, is 0.55 m. m. and it has a uniformity coefficient of 1.3.

As there had been considerable leakage of sand through the strainer system, in the fall of 1907, a layer of gravel passed through a ¾-inch screen was placed above the strainer cups to a depth of 10 inches. At the same time the shot in the strainers was removed and gravel screened through a ¼-inch screen and over a ⅛-inch screen was substituted.

Washing System. The filters are washed by a reverse current of water taken directly from the force main through a 6-inch wrought iron pipe, and is applied under a pressure of 114 pounds per square inch. The amount and pressure of the water applied may be varied at will and is determined by the degree of opening of the valve in the wash water line. The gutters for carrying away the dirty water are annular troughs of wrought iron plates, the tops of which are 12 inches above the sand. They are of triangular section, 11 inches wide on top and 11 inches deep. In practice they have been found altogether too small and during washing are flooded to a depth of several inches.

Automatic Devices. Loss of head gages indicating the relative height of the water in the effluent piping below that in the filter were installed but have not been in use during the special investigation.

Weston automatic rate controllers are provided on each filter and have proven very satisfactory.

Storage of Filtered Water.

Clear Well. The clear well was built from one of the old wells used for obtaining the ground water supply and is beneath the filter house. It consists of a

stone basin 26½ feet in diameter, and has a capacity of 4100 gallons per foot-depth. During operation there are generally about 8 feet of water carried in the well, with a storage of 33,000 gallons, but the actual available depth is only 4 feet and the working capacity is 16,500 gallons. At the ordinary rate of pumping, 1,900 gallons per minute, there is a storage period of only 9 minutes. The available head on the filters when the clear well is full is 17 feet.

Distributing Reservoir. Two horizontal compound duplex Gordon-Maxwell pumps, each having a capacity of 2,500,000 gallons in twenty-four hours, are provided to lift the water from the clear well to the reservoir. The water is forced under a pressure of 114 pounds per square inch through a 16-inch cast iron main, 3,400 feet long, to the reservoir on a hill about one-half mile northeast of the pumping station. The reservoir is an open basin 250 feet long by 60 feet wide by 12 feet deep and has a capacity of 3,500,000 gallons. The sides are puddled and paved with small rough stone blocks. No provisions are made for cleaning but no trouble has been experienced from tastes or odors, although there have been occasional slight algal growths on the sides and bottom of the reservoir.

EXAMINATIONS.

During the special investigation by the State Board of Health, the plant of the Newark, Ohio, Water Company has been visited six times as follows: On May 17th, June (14-15) and December (5-7), 1906, on February 27-March 1, July (16-18) and October 31st, 1907. Regular examinations were made except on May 17th, 1906, and October 31st, 1907, when the plant was inspected.

At the examinations not only were the efficiencies of the various parts of the plant determined, but a study was made also of the amount and quality of the leakage of ground water into the clear well.

OPERATION.

When operating the plant, water flows by gravity from the intake through the suction into the forebay, from which it is lifted by the raw water pump into the settling tank; from this tank it flows by gravity through the filter into the clear well and is pumped by the high service pumps into the reservoir. The hours of operation have varied during the examinations from two runs of 9 hours each to two runs of 12 hours, beginning at 5:30 A. M. and 5:30 P. M. respectively. During the day runs, the plant is in charge of the chief engineer assisted by another engineer and a fireman, while during the night runs it is in charge of another assistant engineer also assisted by a fireman. All the necessary repairs are made by the day force, for which purpose the extra man is employed.

In Table No. 35 will be found data showing the average daily operation of the plant. These figures are compiled from records kept by the chief engineer for the State Board of Health during these investigations.

Average Daily Consumption.

From the records, it will be seen that during the last year there has been but a slight increase in the average daily consumption, which has averaged about 2,200,000 gallons per day. The nominal capacity of the filter plant is but 2,000,000 gallons with no allowance made for the decreased output owing to the fact that the filters are frequently out of service during washing. There has been a continued addition to the quantity filtered due to the seapage of ground water into the clear well which originally formed one of the main sources of the supply. During three examinations

there were obtained measurements of the quantity of water filtered and pumped and the difference between these two quantities has been assumed to be a measurement of the seapage into the clear well. The amount of seapage so determined is shown in the following table:

December 5, 1906	221,000 gals.
December 6, 1906	782,000 "
March 1, 1907	520,000 "
July 17, 1907	700,000 "

The plant is operated at its maximum capacity, and at times when the river is very turbid, it would be impossible to obtain a sufficient supply if it were not that the seapage into the clear well is then increased by the raising of the level of the ground water.

Two bi-passes are provided at the plant, by one of which river water may be taken from the forebay into the clear well, and by the other, which was originally used as a direct intake during such times as the river was clear, water may be taken from a point immediately above the dam through a tile pipe directly into the clear well. The latter intake has occasionally been used during emergencies arising from the clogging of the regular intake caused by the fact that the gravel composing the bed of the river has shifted and has closed the openings in the intake box. The regular intake is of too small capacity and it is frequently possible to supply just a sufficient quantity of water necessary to operate the filters.

Application of Coagulant.

On the examinations of June 14th and December 5th, 1906, it was found that the alum then in use at the Newark plant was not of a satisfactory quality, as was shown by the fact that when similar samples were treated with this alum and that of the Excelsior brand, a considerably greater period of time was required for the formation of the coagulation with the former than with the Excelsior brand. Subsequently, a much more satisfactory brand has been obtained at but a slight increase in cost.

The alum solution is generally mixed continuously, that is to say that several shovelfuls are thrown at regular intervals into a perforated box in the top of the storage tanks through which box a constant stream of water is passed from a perforated pipe. The solution is pumped from the bottom of the storage tanks at approximately the same rate that the water is applied at the top. This method has generally proven fairly satisfactory on account of the considerable storage period allowed in the solution tanks.

On two different occasions during examinations of the plant the solution pipes have become clogged with a hard yellow scale, which formed in the pipes to a thickness of nearly one-half inch, and for the removal of which it was necessary to knock down and clean the pipes. This was due to the poor quality of the alum which contained considerable impurities.

The amount of coagulant used is shown in the table of daily records and has averaged 0.8 grain per gallon during both 1906 and 1907. The maximum amount used, as shown in the daily records, has been 3.8 grains per gallon, and in general it may be said that, when the river is very turbid the maximum amount of alum that can possibly be applied by the available means has been used.

Coagulating Tank.

The method of using the coagulating tank requires little comment as it serves simply as a storage required for the completion of the chemical reaction and the deposition of the heavier particles of suspended matter. It has occasionally been

found that the float and butterfly valves on the filters have not worked satisfactorily and that water has flowed over the top of the filters and into the clear well below. This probably happens more often at night than during the day, as there is but a very poor illumination of the plant and it is difficult to give the filters the necessary attention during the night.

FILTERS.

The Weston controllers have been found to govern the rate of filtration very satisfactorily, and frequent measurements have shown that the filters are generally operated at very nearly 125,000,000 gallons per acre per day. The controllers serve also as loss of head gages, as it is possible to tell from the position of their floats when the filters need washing.

The necessity for washing is shown not only by the fact that the rate of operation is decreased when the filters are dirty, but also from the fact that when the filters are dirty the effluent suddenly becomes turbid. This has been true at Geneva also, where a similar type of filter is in use.

The rate at which the wash water is applied has been measured frequently, and has been found to vary from 10 to 14 inches per minute, but the average rate is probably very nearly one vertical foot per minute. The average number of washes per day as shown by the daily records of the plant is 8, while the maximum number is 28, corresponding to 26 per cent. of wash water. The latter figure is very high, and during such times as the river is very turbid it is found difficult to obtain a sufficient quantity of filtered water, as a great deal of time is lost in washing the filters. During the examination of December 6th, one of the filters was out of service practically all of the time. The average per cent. of wash water for 1906 was 9.4 and for 1907 was 7. Both of these figures are unusually large and are due to the absence of mechanical agitators in the filters, to the comparatively short period allowed for coagulation and sedimentation, and to the small amount of coagulant generally applied.

During washing, the gutters are flooded several inches, and the portion of the filtered area that is best drained is first cleaned; on this account it is necessary to wash the filters longer than if the entire area cleaned with equal rapidity. The quarter method of washing has not been found efficient, and is not in use. The usual rate of applying the wash water is generally sufficient to clean the entire area in about 8 minutes, while the quarter method of washing requires much more time. On account of the small storage capacity of the clear well, it is necessary to slow down the high service pumps when the filters are washed.

Considerabe trouble has been experienced with the strainers. Until the improvements made in the fall of 1907, the wash water was not evenly distributed over the entire filter area, but the application was greatest over the strainer cups. Moreover, the shot contained within the cups had corroded and become massed together. The wash water forced this mass up against the perforated plates, lifted them from their seat and occasionally gave them a permanent set in this position. Leakage of sand through the strainers into the clear well followed and resulted in pacing the gutters too high above the surface of the sand to permit of the satisfactory washing of the filters and also left too shallow a depth of sand to give satisfactory purification. On two occasions, in February and September, 1907, it was necessary to clean out the clear well and replace the sand in the filters. In the fall of 1907, the shot contained in the strainer cups was replaced with gravel, and a 10-inch layer of gravel placed over the top of the strainers, as has been previously described. Since this time a decided improvement has been noted in the efficiency with which the filters have washed, a fact which is shown also by the comparatively low percentages of wash water. (See the daily records). During the inspection

of October 31st, the engineer stated that the wash water had never been so well distributed through the sand as has been the case since these changes were made.

CHARACTER OF RAW WATER.

During each of the several examinations, samples of the untreated water were obtained from a tap in the force main near the raw water pump. There has been such large variations in the quality of the water in the river that its character as determined at the several examinations will be discussed in turn.

The examination of June 14th to 16th, 1906, followed a period of continued fair weather and represents the normal condition of the river. The evidence shows that it was composed largely of ground water, had a low turbidity, and a high alkalinity. The bacterial analyses show considerable numbers of bacteria but no coli in any of the samples taken. The river is fed by several large springs a few miles above the intake of the waterworks, and it is apparent that its flow was then maintained largely by these springs.

The results obtained at the examination of December 5th to 7th, 1906, are among the most interesting of those obtained, as they show to what very rapid changes the river is subject. The examination followed a period of continued fair weather, but on the night of December 5th there was a very heavy rain storm followed by a rapid rise in the river which continued until about 3:00 P. M. of December 6th. The total rise was about 6 feet. It is interesting to note the very sudden changes in the river water caused by this rise. These changes are shown by the increase in the turbidity from 25 to 700 parts per million in 12 hours and a corresponding bacterial content from 4,200 to 184,000 per c. c. It should be noted that no coli were found in any of the samples taken. There was an increase in dissolved color, while the alkalinity reduced from 200 to 90 parts per million. It will be seen, however, that the river cleared up as rapidly as it became turbid, although on December 7th there was a continued high bacterial content, even after the crest of the rise. This crest occurred in the middle of the afternoon of December 6th. The engineer stated that these were representative of the worse conditions that are ever experienced at the plant, and under "Efficiency of Plant" is shown what a serious effect these conditions have on the possibility of easily obtaining a satisfactory effluent from the filters.

During the examination of February 27th to March 1st, 1907, which examination followed a period of continued fair weather, the river was low and practically stationary. As on June 14, 1906, the flow was maintained largely by springs, and the alkalinity was high, color low, while the bacterial content was fairly high considering the source of the water. No coli were found in any of the samples taken.

The examination of July 17th and 18th, 1907, followed a very heavy rain on the night of July 16th, and although the river had been low it was rising during the examination. The crest of the rise was reached at about 7:00 A. M. July 18th. The samples again show a very rapid change in the character of the raw water, as is indicated by the increase in turbidity and continued decrease in the alkalinity, although the increase in bacterial content was not so great, as had been experienced on December 5th. The presence of coli in considerable numbers in all of the samples is most significant and shows that there was a considerable pollution of the river water.

From the above discussion it will be seen that the examinations have covered nearly all the ordinary weather conditions which have a decided influence on the character of the river water. Except after heavy rains the flow in the river is maintained largely by springs, and the water is clear, practically colorless and, although somewhat hard, is evidently of satisfactory quality for domestic use even without purification. On account of the generally steep slope of the watershed the

stream is subject to very rapid rises causing extensive changes in the raw water in a remarkably short period of time. Following periods of heavy rains it is turbid and is liable to contain considerable pollution, although the evidence woud show that this is not necessarily the case, as in but one of the two examinations during such rapid changes has there been found any evidence of pollution in the river.

In general it may be said that the water of the river is comparatively easy to handle and requires but little purification; but that at times it undergoes very rapid and considerable changes, which do not as a rule last more than 48 hours. While they do last, however, the river is turbid, may contain considerable pollution and great care is necessary for its purification.

EFFICIENCIES.

Guarantee.

In the contract furnished by the filter company is contained the guarantee that the water shall be clear and colorless, and that when the raw water contains 3,000 or more bacteria per c. c. there shall be a removal of at least 97 per cent.; when the river water contains less than 3,000 per c. c., not more than 100 bacteria per c. c. shall be found in the effluent.

Coagulating Basin.

During each examination samples were taken from the top of one of the filters in order to obtain information in regard to the satisfactory preparation of the water for filtration. It has as a rule been found that a very small amount of coagulant has been used, especially during the first two examinations, on the first of which practically no bacterial removal was obtained by the coagulating basin. The maximum bacterial efficiency obtained by the basin was 66 per cent., and occurred during a period of low turbidity in the river. On December 6th, 1906, when the river was turbid, but 26 per cent. of the bacteria were removed by the basin, and there was a comparatively large amount of suspended matter contained in the water on the filters. At this time considerable more coagulant was used than when the water was clear, but it is apparent that the coagulating basin has not sufficient capacity to permit a successful and economical operation of the plant during such conditions as then prevailed.

The results on the examination of February 27th, 1907, are of particular interest, as it was noted that there was no visible coagulation in the applied water on the filters. As it was thought that the absence of suspended matter in the river water was largely responsible for the difficulty in obtaining coagulation, samples of the raw water were treated with amounts of coagulant varying from one to four grains per gallon, and it was noted that but a light precipitate formed in any of the samples even four hours after the application. No precipitate formed with two grains per gallon. The alum used was the Calumet brand of the General Chemical Company, and these results were checked by similar experiments performed using the Excelsior brand of the Pennsylvania Salt Company.

In order to determine whether the addition of clay would assist the coagulation, clay in suspension was added to three samples of raw water until the resulting turbidity was approximately 20 parts per million; two, three and four grains per gallon respectively of alum were then added. The coagulation was well started in one hour in all the samples, and there was a very good precipitate in one and one-half hours.

These results were shown the engineer at the plant, and the use of clay was recommended to start the coagulation at times when the raw water con-

tained but little suspended matter, but it was subsequently learned that these recommendations were not followed.

It is occasionally necessary to use as much as 26 per cent. of wash water, due to the fact that the applied water is not properly prepared for filtration, and contains too much suspended matter. The large average amount of wash water used is due to the lack of agitation in the filters, to the use of too small amounts of coagulant, and to the fact that there is not sufficient sedimentation in the coagulating tank. Longer storage would permit the use of less alum, require less wash water, and, what is of the greatest importance, would permit of the successful operation of the plant during such times as the river is very turbid.

Filters.

During all of the examinations more than 3,000 bacteria per c. c. were found in the raw water, but the highest bacterial removal by the plant was 92 per cent. There are several reasons for these poor efficiencies. On the first examination it was apparent that but a low degree of purification was necessary, and a smaller quantity of coagulant was used than was required for a high bacterial removal. On the second examination, the poor removal by the filters was due primarily to the unsatisfactory operation of the coagulating basin on which account too great a load was placed upon the filters. On the examination of February 27th, but little purification was required, and the poor results obtained were in part due to the clogging of the alum solution pipe. The results obtained at this time are representative of the degree of purification obtained by a mechanical filter without coagulation. The poor results of the last examination were directly due to the condition of the filters which resulted from a leakage of sand through the strainers. The depth of sand then in the filters is shown in the following table:

Filter No. 1	1.2	feet
" " 2	2.2	"
" " 3	2.7	"
" " 4	1.6	"

The crests of the gutters of the various filters were too high above the sand to permit a satisfactory wash, as will be shown in the following table:

Filter No. 1	3.1	feet above the sand
" " 2	2.1	" " " "
" " 3	1.6	" " " "
" " 4	2.7	" " " "

As a result of the poor washing of the sand, it was found to be generally hard and even after washing to be clogged to such an extent that it contained cracks several inches deep. This was particularly true around the outside of the filters.

On the inspection of October 31st, 1907, these conditions were immensely improved, due to the increased efficiency in the washing caused by the replacing of filtering material and by the introduction of gravel in the strainer cups, and above the strainer system. Although no samples were taken at that time, it was apparent that there was much less difficulty in obtaining satisfactory effluents from the filters.

Quality of Seapage into Clear Well.

At each examination it was endeavored to learn the effect of the considerable leakage of water into the clear well, for which purpose samples were taken from the well, from the emergency intake and from a tap in the force main which contained water representative of that pumped to the reservoir. On the first examination the seapage consisted of ground water and contained very few bacteria. On the second examination, however, the evidence indicates that the seapage was composed partly of ground water and partly of water from the river, as is shown by its color and turbidity. It was stated during this examination that, during periods of exceptionally high water, there is a more rapid flow from the river into the clear well and at such times the water in the well becomes decidedly turbid. As this leakage follows along the emergency intake, it would appear that the latter should be removed, but this is not considered practicable at the present time on account of the necessity for its use during such times as the regular intake is clogged. The conditions on the examination of July 17th are similar to those just described, as it is evident that the leakage contained considerable river water. From its temperature, 18 degrees, as compared with that of the river, 25 degrees, it is apparent that the percentage of ground water is large, but the presence of coli in one c. c. would indicate a considerable contamination by river water.

REVIEW OF EFFICIENCY OF PLANT DURING SPECIAL INVESTIGATION.

From the above discussion of the four examinations of the plant of the Newark Water Company, it is apparent that although the filters have not been giving satisfactory effluents from the standpoint of percentage removal, on but one of the four examinations has the supply been found unpotable. This condition followed a period of continued heavy rains. The poor efficiencies obtained have been due in part to the fact that the coagulating basin has not sufficient capacity, but principally to the leakage of sand through the strainer system. Following the repairs made in the fall of 1907, there should not be a recurrence of such conditions. To the fact that the plant is operated at its maximum capacity is largely due the difficulty in operation experienced during times of high turbidity in the river.

Although the evidence has shown the danger of a possible pollution of the Newark water supply, it is of interest to note in this connection the comparative absence of typhoid fever, which is of rare occurrence and not more than would normally be expected in a city of such size.

Cost of Installation.

It has been impossible to obtain figures of the actual cost of installation of the Newark plant, but the following table shows estimates of replacing it, as contained in appraisements of the plant by two engineering firms — one for the water company and one for the city. The figures are based on present prices for material.

Cost to Replace.	By Company's Engineers.	By City's Engineers.
Distribution System	$175,602 49	$159,508 10
Lands	3,092 00	3,000 00
Buildings	14,400 00	14,400 00
Reservoir	14,000 00	14,000 00
Machinery	16,600 00	16,300 00
Sundry	63,685 25	45,610 00
Total	$287,379 74	$252,818 10

COST OF OPERATION — 1906

TOTAL RECEIPTS		$40,175
Domestic Services	$26,615	
City Hydrant Rentals	13,560	
DISBURSEMENTS:—		
Repairs to mains, hydrants, pumps, boilers, services, buildings, grounds, etc.	$1,027.37	
Salaries and wages to employees	5,737.51	
Fuel, coal — ($1.80 per ton)	6,966.27	
Filter alum — ($0.90 per 100 lbs.)	790.65	
Office rent and supplies, telephone, horse and wagon, oil and waste, and insurance	919.66	
Taxes for the year, local	2,486.33	
Service rate refund	30.21	17,958
EARNINGS		$22,217

Total gallons of water pumped	772,000,000
Total number of tons of coal used	3,870
Total number of pounds of coagulant	71,158
Total cost per million gallons	$23.20
Number tons coal per million gallons	5.0

TABLE NO. 35.

Newark — Record of Operation.

Month.	Average Daily Consumption.	Gallons Filtered.	Wash Water.		Alum Used.	
			Gals.	Per cent.	Pounds.	Gr. per Gal.
1906.						
June	2,080,000	1,405,000	126,000	8.9	102	0.5
July	2,086,000	1,411,000	147,000	10.4	198	0.9
August	2,180,000	1,505 000	158,000	10.5	197	0.9
September	2,222,000	1,547,000	111,000	7.2	139	0.6
October	2,122,000	1,447,000	137,000	9.5	213	1.0
November	2,008,000	1,333,000	134,000	10.1	200	1.0
Average	2,116.000	1,461,000	135,000	9.4	174	0.8
1907.						
January	2,016,000	1,341,000	112,000	8.3	242	1.2
February	2,121,000	1,446,000	96,000	6.6	138	0.6
March	2,035,000	1,360,000	135,000	9.9	283	0.9
April	2,079,000	1,404,000	109,000	7.7	239	0.8
May	.....	.....	.....	.....	.....	.....
June	2,368,000	1,693,000	122,000	7.2	253	1.0
July	.....	.....	.....	.....	.....	.....
August	2,399,000	1,724,000	86,000	4.9	183	0.5
September	2,360,000	1,685,000	117,000	6.9	249	1.0
October	2,280,000	1,605,000	85,000	5.8	176	0.7
November*	1,982,000	1,307,000	74,000	5.7	169	0.9
Average	2,185.000	1,507,000	104,000	7.0	215	0.8

* Plant operated but 25 days.
Amount of ground water assumed — 675,000 gal. per day.
Rate of washing — 1,350 gals. per min.

TABLE NO. 36.

Newark — Results of Analyses During Examinations.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	Temp
	1906	A. M.								
33	6-14	7:45	Raw water	4,900	0	0	16	10	196	17
38	6-14	10:00	Raw water	700	0	0	16	10	205	.....
		M.								
40	6-14	12:00	Raw water	Slipped	.....	.....	.....	10	.....	.....
		P. M.								
45	6-14	2:45	Raw water	850	0	0	10	10	.....	21
			Average	2,200	.....	.....	13	10	200	.....
		A. M.								
34	6-14	8:30	Effluent No. 1	180	0	0	4	0	.....	17
35	6-14	8:30	Effluent No. 2	200	0	0	0	0	.....	17
36	6-14	8:30	Effluent No. 3	300	0	0	.....	0	175	17
37	6-14	8:30	Effluent No. 4	325	0	0	.....	0	.....	17
		P. M.								
41	6-14	12:10	Effluent No. 1	350	.....	.....	.....	0	.....	.....
42	6-14	12:10	Effluent No. 2	190	.....	.....	.....	0	.....	.....
43	6-14	12:10	Effluent No. 3	250	.....	.....	.....	0	.....	.....
44	6-14	12:10	Effluent No. 4	210	.....	.....	.....	0	.....	.....
46	6-14	2:45	Effluent No. 1	250	0	0	6	0	185	21
47	6-14	3:00	Effluent No. 2	75	0	0	0	0	.....	21
48	6-14	3:00	Effluent No. 3	150	0	0	0	0	.....	21
49	6-14	3:05	Effluent No. 4	200	0	0	0	0	.....	21
			Average	223	.....	.....	5	0	180	.....
		A. M.								
29	6-14	11:30	Reservoir	70	0	0	8	0	170	22
30	6-15	5:55	Raw water	1,500	0	0	16	10	.....	18
55	6-15	9:00	Raw water	1,400	0	0	12	10	.....	19
66	6-15	11:00	Raw water	1,700	.....	.....	8	.....	200	21
		P. M.								
67	6-15	1:15	Raw water	1,300	0	0	.....	.....	200	24
71	6-15	3:30	Raw water	650	.....	.....	.....	.....	.....	.....
			Average	1,310	.....	.....	12	10	200	.....
51	6-15	7:00	Effluent No. 1	50	.....	.....	0	0	.....	18
52	6-15	7:00	Effluent No. 2	180	.....	.....	2	0	.....	18
53	6-15	7:00	Effluent No. 3	37	.....	.....	0	0	.....	18
54	6-15	7:00	Effluent No. 4	60	.....	.....	0	0	.....	18
56	6-15	9:30	Effluent No. 1	475	.....	.....	.....	0	.....	19
57	6-15	9:30	Effluent No. 2	32	.....	.....	2	0	.....	19
58	6-15	9:30	Effluent No. 3	95	.....	.....	.....	0	.....	19
59	6-15	9:30	Effluent No. 4	28	.....	.....	2	0	.....	19
63	6-15	11:15	Effluent No. 1	16	.....	.....	.....	.....	.....	.....
64	6-15	11:15	Effluent No. 2	80	.....	.....	.....	.....	.....	.....
65	6-15	11:15	Effluent No. 3	34	.....	.....	.....	.....	.....	.....
65	6-15	11:15	Effluent No. 4	280	.....	.....	.....	.....	.....	.....
			Average	114	.....	.....	2	0	.....	.....
60	6-15	10:30	Clear well	Slipped	0	0	0	0	210	12
61	6-15	11:00	Clear well	625	.....	.....	.....	.....	.....	.....
		P. M.								
68	6-15	1:30	Clear well	140	.....	.....	.....	.....	.....	.....
69	6-15	3:00	Clear well	70	.....	.....	0	0	180	22
			Average	278	.....	.....	.....	.....	195	.....
70	6-15	3:30	Seapage into clear well	10	.....	.....	0	0	210	18

TABLE NO. 36 — Continued.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	Incr.
	1906	A. M.								
831	12-5	6:30	Raw water	5,000	0	0	20	25	200	....
838	12-5	10:30	Raw water	3,500	0	0	15	.....	198	.....
833	12-5	9:00	Set. water top No. 4	2,900	.....	.....	.....	.....	196	.....
		P. M.								
844	12-5	2:00	Set. water top No. 4	6,000	.....	.....	.....	.....	.....	.....
		A. M.								
834	12-5	9:30	Effluent filter No. 1	1,100	.....	.....	6	<5	192	.....
835	12-5	9:30	Effluent filter No. 2	850	.....	.....	6	<5	.....	.....
836	12-5	9:30	Effluent filter No. 3	1,000	.....	.....	6	<5	.....	.....
837	12-5	9:30	Effluent filter No. 4	1,100	.....	.....	6	<5	.....	.....
		P. M.								
840	12-5	2:00	Effluent filter No. 1	1,100	.....	.....	8	<5	.....	.....
841	12-5	2:00	Effluent filter No. 2	1,500	.....	.....	8	<5	.....	.....
842	12-5	2:00	Effluent filter No. 3	1,500	.....	.....	8	<5	189	.....
843	12-5	2:00	Effluent filter No. 4	1,200	.....	.....	10	<5	.....	.....
			Average	1,170	.....	.....	7	<5	191	.....
		A. M.								
832	12-5	8:30	Tap from force main	1,100	0	0	8	<5	196	.....
839	12-5	11:30	Tap from force main	900	0	0	6	<5	192	.....
847	12-6	10:00	Raw water	127,000	0	0	32	650	128	32
		P. M.								
852	12-6	2:00	Raw water	184,000	0	0	32	700	90	.....
			Average	155,000	0	0	32	675	114	.....
		A. M.								
849	12-6	11:00	Effluent filter No. 2	5,700	.....	.....	15	<5	128	.....
850	12-6	11:00	Effluent filter No. 3	7,800	.....	.....	15	<5	.....	.....
851	12-6	11:00	Effluent filter No. 4	4,400	.....	.....	10	<5	.....	.....
		P. M.								
855	12-6	3:00	Effluent filter No. 1	24,000	.....	.....	.....	.....	.....	.....
856	12-6	3:00	Effluent filter No. 2	28,000	.....	.....	.....	.....	.....	.....
857	12-6	3:00	Effluent filter No. 3	29,000	.....	.....	30	20±	63	.....
858	12-6	3:00	Effluent filter No. 4	21,000	.....	.....	.....	.....	.....	.....
			Average	17,100	.....	.....	18	8	96	.....
	1906	A. M.								
845	12-6	6:45	Reservoir	850	0	0	12	10±	180	52
846	12-6	8:45	Tap at Warden Hotel	850	0	0	10	5±	180	35
		P. M.								
854	12-6	3:00	Tap in force main	6,900	.....	.....	20	<5	.....	.....
853	12-6	2:00	Seapage into clear well	(Lost)	.....	.....	25	20±	186	.....
		A. M.								
859	12-7	7:30	Raw water	165,000	0	0	50	165	96	.....
861	12-7	8:00	Effluent filter No. 3	12,000	.....	.....	35	10±	52	.....
863	12-7	10:00	Effluent filter No. 3	(Lost)	.....	.....	15	<5	57	.....
862	12-7	9:00	Reservoir	5,500	.....	.....	25	10±	168	.....
860	12-7	8:00	Tap in force main	5,000	.....	.....	35	15±	78	.....

TABLE NO. 36 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	CO_2
1045	1907 2-27	P. M. 3:00	Raw water	.....	0	0	6	7	185	—2
1048	2-28	A. M. 7:00	Raw water	6,000	0	0	6	7	190	.....
1057	2-28	P. M. 1:45	Raw water	4,800	0	0	.....	7	190	.....
1060	2-28	A. M. 7:00	Raw water	5,400	0	0	.....	7	190	.....
1046	2-27	P. M. 3:00	Settled water	1,800	0	0	.....	.....	183	1.0
1049	2-28	A. M. 7:00	Settled water[1]	3,200	0	0	.....	.....	188	.....
1058	2-28	P. M. 1:45	Settled water	4,500	0	+	.....	.....	188	.....
1061	3-1	A. M. 7:00	Settled water	5,000	0	0	.....	.....	188	.....
1051	2-28	9:00	Effluent filter No. 1	700	.....	.....	.....	.....	.....	.....
1052	2-28	9:00	Effluent filter No. 2	520	.....	.....	.....	.....	.....	.....
1053	2-28	9:00	Effluent filter No. 3	100	.....	.....	5	5	190	2.0
1054	2-28	9:00	Effluent filter No. 4	1,200	.....	.....	.....	.....	.....	.....
1047	2-27	P. M. 3:00	Tap in force main	780	0	0	5	5	183	1.0
1050	2-28	A. M. 7:00	Tap in force main	720	0	0	4	5	186	.....
1055	2-28	10:30	Tap in force main	.....	0	0	5	5	188	.....
1059	3-1	P. M. 1:45	Tap in force main	5,400	0	0	4	5	187	.....
1062	3-1	A. M. 7:00	Tap in force main	900	0	0	5	5	187	.....
1056	2-28	M. 12:00	Reservoir	2,800	0	0	5	5	87	.....
1502	1907 7-17	A. M. 8:00	Raw water	2,350	+	+	15	40	179	.....
1510	7-17	P. M. 12:30	Raw water[1]	3,900	+	+	25	110	164	.....
1517	7-17	5:00	Raw water	4,800	+	+	35	190	160	.....
			Average	3,500	+	+	25	118	168	.....
1503	7-17	A. M. 8:00	Set. water from top No. 3	1,700	+	+	.....	60	174	.....
1511	7-17	P. M. 12:30	Set. water from top No. 3	2,900	0	+	.....	60	159	6
1518	7-17	5:00	Set. water from top No. 3	3,200	.....	.....	.....	90	160	.....
			Average	2,600	.....	.....	.....	70	161	.....
1504	7-17	A. M. 8:30	Effluent filter No 1	1,000	.....	.....	8	<5	172	.....
1505	7-17	8:30	Effluent filter No. 2	300	.....	.....	9	<5	172	.....
1506	7-17	8:30	Effluent filter No. 3	1,000	.....	.....	8	<5	172	.....
1507	7-17	8:30	Effluent filter No. 4	1,000	.....	.....	8	<5	172	.....
1513	7-17	P. M. 3:00	Effluent filter No. 1	450	.....	.....	12	<5	155	.....
1514	7-17	3:00	Effluent filter No. 2	240	.....	.....	12	<5	155	.....
1515	7-17	3:00	Effluent filter No. 3	450	.....	.....	12	<5	155	.....
1516	7-17	3:00	Effluent filter No 4	240	.....	.....	12	<5	155	.....
			Average	850	.....	.....	10	<5	164	.....

[1] Alum pump not running, no coagulant applied.
[2] Sample No. 1510, phen. alk., 1.0; temp., 25 deg.

TABLE NO. 36 — Concluded.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			C. C. 1	C. C. 100	Col.	Turb.	Alk.	CO_3
1508	7-17	A. M. 8:30	Tap in force main.....	1,200	+	+	8	<5	176	.....
1512	7-17	P. M. 12:30	Tap in force main.....	240	.....	.....	15	<5	168	2
1519	7-17	5:00	Tap in force main.....	500	0	+	20	<5	158	.....
			Average	650	.....	.....	14	.....	167	.....
1509	7-17	A. M. 11:30	Leakage into clear well[1]....	780	+	+	15	5±	190	.....
1520	7-18	7:00	Raw water	9,000	0	+	45	180	131	1.5
1528	7-18	11:00	Raw water[1]	3,600	+	+	35	140	124	.....
			Average	6,300	.....	.....	40	160	128	.....
1521	7-18	7:00	Set. water from top No. 8..	2,100	.....	.....	26	160	132	11
1529	7-18	11:00	Set. water from top No. 8..	2,700	+	+	33	160	114	.....
			Average	2,400	.....	.....	30	160	123	11
1523	1907 7-18	A. M. 8:00	Effluent filter No. 1.....,	630	.....	.....	50	5±	121	5
1524	7-18	8:00	Effluent filter No. 2.....,	840	.....	.....	50	5±	121	5
1525	7-18	8:00	Effluent filter No. 3.....,	810	.....	.....	50	5±	120	8
1526	7-18	8:00	Effluent filter No. 4.....,	570	.....	.....	50	5±	120	7
			Average	710	.....	.....	50	5±	121	.....
1522	7-18	7:00	Tap in force main.....	840	0	+	30	5±	130	.....
1530	7-18	11:00	Tap in force main.....	450	+	+	35	5—	124	.....
			Average	650	.....	.....	33	5	127	.....
1527	7-18	9:30	Reservoir	510	0	+	12	5—	152	.....

Sample No. 1509, temp. 18 deg., incr. 25, iron, 2.5.
Sample No. 1528, incr. 40, iron 1.8.
Sample No. 1527, incr. 35, iron 1.0.

POMEROY and MIDDLEPORT.

The villages of Pomeroy and Middleport are situated in the south central portion of Ohio in Meigs County on the Ohio River. In 1906 the population of Pomeroy was estimated at 4,600 and of Middleport at 4,000. These towns are two of the oldest in the state and both contain a number of coal mines and also several salt and calcium works.

HISTORICAL.

The waterworks were installed in 1899 by the Pomeroy & Middleport Water Company and the supply was obtained directly from the Ohio River at a point opposite the upper end of Pomeroy and about 800 feet above the mouth of Kerr's run.

The condition of the water of the Ohio River at Pomeroy was investigated

for the Ohio State Board of Health in 1901. It was found that the water at Pomeroy was representative of the stream, as there was no local pollution. The nearest cities of any size above the intake of the waterworks are Parkersburg and Marietta, which are about 60 and 70 miles, respectively, above Pomeroy. The population of Parkersburg is 11,700 and of Marietta is 15,500. The sewage of all of the towns on the Ohio is discharged directly into the river without purification, and while there is a very large dilution, sufficient to obliterate any nuisance, yet the water at all points is unwholesome without purification, a fact which is confirmed by the presence of coli in 60 per cent. of the samples taken at the several points on the river during the investigations in 1901. Also the river contains at times very large amounts of suspended matter during periods of high water, which are frequently of several days duration.

On account of the pollution of the river water and its unsatisfactory appearance, it was necessary to provide a purification plant when the waterworks were installed at Pomeroy.

DESCRIPTION OF PLANT.

The waterworks installed at Pomeroy in 1899 comprise an intake, low and high service pumps, a steel settling tank, a pressure filter, a storage reservoir and a distributing system. The pumps are housed in a substantial brick building located at the extreme upper end of Pomeroy, above any local pollution.

Intake and Raw Water Pump.

The intake, consisting of a 10-inch cast iron pipe, extends 150 feet into the river from the pumping station, and 30 feet beyond the low water shore line. The minimum depth of water at the mouth of the intake is 5 feet. The pipe is laid directly on the bottom and no provision is made for drawing water from any other level.

The raw water pump is of the horizontal compound, duplex type of 500,000 gallons capacity, and is placed in a well 18 feet in diameter by 48 feet deep. Its maximum suction is 15 feet above extreme low water. It discharges through a 10-inch cast iron pipe which leads to the bottom of the settling tank located on a hill immediately back of the pumping station.

Settling Tank.

The settling tank is 35 feet in diameter by 35 feet high and has a capacity of 235,000 gallons. The total lift to the basin when full is 150 feet above the raw water pump. The outlet of the tank is a floating tube with an elbow joint, and the point of discharge is maintained at a depth of one foot below the surface of the water in the tank. This tube, however, was constructed of too light material and during the special investigation by the State Board of Health, has not been in operation, so that the discharge was from a point about 7 feet above the bottom of the tank. The top of the settling tank is 56 feet above the filter to which the water flows by gravity.

Means for Applying Coagulant.

The coagulant used at Pomeroy is aluminum sulphate, obtained from Harrison Bros. & Co., Philadelphia, Pa. Two wooden tanks are provided for the preparation and storage of its solution, one 2 feet square by 2 feet deep, and the other 4 feet square by 4¾ feet deep. The tops of both tanks are at the same level, and there is a connection from the force main into the first, or smaller tank, which also contains a float valve for the regulation of the height

of water. The outlet of the second tank is from the bottom and leads to a small pump directly connected to the high service pump, and by this means the rate of application of the coagulant varies with the rate at which the filter is operated. The small pump forces the solution into the pipe supplying the filter.

The solution was originally prepared in a small iron tank, which was eaten out by the acid in the alum, and the above system of tanks was installed in March, 1907.

Filter.

The filter consists of a horizontal steel tank 25 feet long by 8 feet in diameter, and has much the appearance of a barrel supported on its side. Concrete is placed in the bottom of the filter to a depth of 2 feet or just below the collectors which consist of ten, 2½-inch brass pipes. The collectors are perforated and surrounded by a brass screen for the purpose of holding back the sand. There are no perforations within 3 feet of either end of the collectors and when the sand in the filter was removed it was found to be hard and impervious where there were no perforations. Over the strainer system is placed 4.0 feet of filter sand. This was originally obtained from Sea Girt, N. J. and was of the coarse grade usually placed in mechanical filters. It was replenished in the spring of 1907 with sand from the Ohio River at a cost of but $1.00 per ton. It has an effective size of 0.35 m. m. and a uniformity coefficient of 1.5, and has proven very satisfactory.

The average effective area of the sand is 145 square feet or .00333 acre, which, at 125,000,000 gallons per acre per day, gives a nominal capacity of 420,000 gallons for 24 hours.

Connections are provided by which the filter may be washed with a reverse current of water obtained either from the settling tank or from the force main. The dirty water is removed through one of the branches in the tee in the top of the filter, while in the other branch is the connection by which settled water is applied to the filter.

Storage of Filtered Water.

The effluent pipe from the filter is directly connected to the clear water pump, which is a horizontal compound duplex Buffalo pump of 500,000 gallons capacity. This pump lifts the water to the distributing reservoir on Lincoln hill, two miles from the pumping station at an elevation of 302 feet above the low water mark of the river. The reservoir is lined with brick masonry and is 65 feet in diameter by 13 feet deep, with a capacity of 275,000 gallons. In the bottom is a drain by means of which the reservoir may be emptied for cleaning purposes, and as the basin is uncovered it has been found necessary to clean it every spring to remove growths.

EXAMINATIONS.

During the special investigation by the State Board of Health, the plant of the Pomeroy & Middleport Water Company has been visited four times, on July (24-25), November (19-20), 1906, May 16th and November 6th, 1907. On the first three visits regular examinations were made while on November 6th, 1907, the plant was inspected.

OPERATION.

During the operation of the Pomeroy plant the river water is pumped to the settling tank, from the top of which it flows by gravity to the filter and is

pumped into the distributing reservoir. The coagulant solution is applied to the settled water as it enters the filter. As no storage for filtered water is provided at the plant, and as the high service pump is directly connected to the effluent pipe of the filter, the rate at which the filtered water is pumped determines also the rate of filtration.

During the first part of the investigation, and until May, 1907, the entire run at the pumping station was conducted by one man who did his own firing and attended to the operation of the pumps and filters. In order to furnish the required amount of filtered water in a reasonable time it was necessary to run the pump at very nearly its maximum capacity, a fact which caused such high rates of filtration that it was impossible to secure satisfactory results. Since May, 1907, an assistant has been employed to run the plant during the evening, and the length of time during which it is now operated has been increased from 10 to 17 hours.

As the engineer has but little time available, it has been found difficult to obtain complete daily records at the Pomeroy plant, so that but five months operation during 1907 is shown in Table No. 37.

Average Daily Consumption.

From the daily records it will be seen that there is a large seasonal variation in the quantity of water pumped daily at Pomeroy, and that the average daily consumption varies from 188,000 to 349,000 gallons. It is probable that the average quantity pumped daily during the year is about 260,000 gallons.

Application of Coagulant.

Although when the filter plant was installed it was thought that the use of a coagulant would be unnecessary, this was not found to be the case, and a coagulant has been used since the early operation of the plant. The solution of the coagulant is prepared by adding a few shovelfuls of alum at regular intervals to the first tank through which the water is passed into the second at the same rate as that at which the solution is pumped. It will be seen that the second tank serves not only for storage but tends to equalize and keep the solution at practically a constant strength. In order to vary the amount of coagulant applied, it is only necessary to change either the frequency with which the charges are introduced into the solution tank, or the quantity of solution applied by varying the length of the stroke of the solution pump.

The average quantity of coagulant applied, as shown by the daily records, is 57 pounds per day or 1.6 grains per gallon. It is of interest to note that practically the same quantity is used no matter what the condition of the water in the river. The maximum quantity as indicated on the daily records is 3.3 grains per gallon on January 13, 1907, at which time the river had a turbidity of 1,500 parts per million. During the latter half of July, 1907, the river was very muddy and contained 1,500 parts per million of turbidity, yet even under these conditions an average amount of but one grain of coagulant per gallon was applied. It is apparent that from a false sense of economy there is a tendency to use too small a quantity of coagulant.

During the first examination it was recommended that the point of application of the coagulant be changed and that the solution be pumped into the pipe through which raw water is supplied to the settling tank. This was not done, as it was feared that the acid in the alum solution would tend to attack the steel settling tank.

Settling Basin.

The average theoretical time allowed for sedimentation in the settling tank is about 9¾ hours. During the special investigation the latter tank has served both as a means for providing preliminary sedimentation and preparation of the water for the filter, and also to furnish the head necessary to operate the latter. At the first examination the floating outlet by which the point of discharge from the tank is controlled was out of service, as it had rusted and collapsed near the joint. It was then recommended that this tube should be immediately repaired, which, however, was not done until January, 1907. When repaired in January, the chain by which the tube was attached to the float was of too light material and the plant had been operated but a few days when this chain broke, and the tube went to the bottom. Although the economic necessity for keeping this tube in repair was advised on several occasions, it was not until October 17th, 1907, that the tube was again connected to the float. During practically seventeen months of the investigation water has been drawn from the settling basin at a point about 7 feet above the bottom, and the river water has been applied to the filter very nearly in its original condition. On this account it has been necessary to use unnecessarily large quantities of wash water, a fact which is to be regretted, as the repairs to the floating tube required practically no expense, but merely a little attention on the part of the superintendent. Not only has the expense of operating the plant been unnecessarily large but it is probable also that its efficiency has been lessened as a greater burden has been thrown on the filter than should have been the case.

Filter.

As the high service pump is directly attached to the effluent of the filter, the rate of filtration is regulated by the speed at which the pump is operated. When installed it was intended to operate the filter at the rate of 125 million gallons per acre per day, but from the daily records it will seem that the average rate during 1907 has been about 145 million gallons per acre per day. As the capacity of the filter is about 420,000 gallons in 24 hours, it is apparent that, particularly during the summer, the plant should be operated for very nearly 24 hours in order to avoid excessive rates, or that another filter unit should be provided.

On the examination of July 24, 1906, but one man was employed to operate the plant, and the daily consumption was 280,000 gallons. During the morning the rate of filtration was 173 million gallons per acre per day, which also was found to be the average rate on November 19th, 1906. On May 16th, 1907, an assistant had been employed, and the length of time during which the plant was operated was increased from 10 to 17 hours. At this examination the average rate was 151 million gallons per acre per day, which is not far from the rate that has prevailed during the months following.

As indicated by the pressure gage, the total available head at the filter after it is washed is 58 feet, and as the initial loss of head when the filter is started in service is 8 feet, the total increase during its operation is 50 feet. The necessitty for washing the filter arises, not from the fact that the total available head is exhausted, but that near the end of the run the effluent from the filter suddenly becomes turbid. It is then customary to shut off the filter and to wash it by a reverse current of water obtained first from the settling tank, which water is applied for about 10 minutes, and then to finally rinse out the sand for 3 minutes using clear water obtained from a connection to the force main. The water in the settling basin is generally lowered about 2 feet while the filter

is washed, and the quantity of settled water applied is about 14,000 gallons. The filtered water is applied at a considerably less rate, and the total quantity used is approximately 2,000 gallons.

It is necessary to wash the filter on an average of from three to four times per day throughout the year, and occasionally when the river is very muddy, once every hour. From the few daily records available, it is apparent that the average quantity of wash water used is not far from 26 per cent. of the average daily consumption. This quantity is very large and the expense of operating the plant has been largely increased from the fact that the settled water applied to the filter has been but little clearer than that in the river. It was to decrease largely the quantity of wash water that recommendations were made to keep the floating outlet of the basin in repair, and to change the point of application of the coagulant.

CHARACTER OF RAW WATER.

During each of the several examinations samples of river water were obtained from a tap at the raw water pump. The evidence obtained indicates considerable variation in the character of the raw water at Pomeroy, corresponding to changes in the weather conditions.

Examination of July 24th, 1906.

On July 23rd, there had been a very heavy local rain on the watershed above Pomeroy and during the examination the river was in an unusually turbid condition. Although the turbidity of the river was 1,000 parts per million, there were but 19,000 basteria per c. c. It is apparent that the river was clearing up, as is shown by the increase in alkalinity.

Examination of November 19th, 1906.

On November 19th, 1906, the river was unusually clear, although it contained considerable dissolved color. During the night of November 19th, however, a heavy rain caused a sudden rise of about 6 feet in the river, and it is of interest to note the increase in turbidity with but a comparatively small increase in bacteria.

Examination of May 16th, 1907.

Fair weather prevailed during the examination of May 16th. The river was at about a 20 foot stage and the rapid decrease in turbidity and slight increase in alkalinity indicated that it was falling. The results of this examination are of particular interest as it is the first in which coli, indicating recent pollution, were found in the river water. The decrease in the number of coli as the examination continued indicate that they were due to the rise in the river.

A review of the above discussions show that while the Ohio River at Pomeroy frequently contains very large quantities of suspended matter, and at certain seasons of the year considerable dissolved color, on which account it is of very objectionable appearance, but little evidence has been obtained showing recent sewage pollution. Under ordinary conditions it is not necessary to obtain a high bacterial purification of the river water but merely to improve its physical appearance.

EFFICIENCIES.

Application of Coagulant.

The method of applying the coagulant solution at Pomeroy is such that it is impossible for the engineer to tell at what rate the solution is pumped. This was shown very well on the examination of November 19th, 1906. From the alkalinity determinations of the raw and treated water on the morning of November 19th, it is apparent that no coagulant had been applied, and when the engineer was informed of this fact he expressed surprise, as the coagulant solution was even stronger than usual. The alum pump was apparently working satisfactorily, but, when taken apart, it was found that one of its valves was not in working order, so that no solution was actually pumped. The analyses of the samples taken from the mains indicate that there had been no alum applied on the day previous to the examination also. The necessity for the regular application of the coagulant is indicated by the poor results first obtained and by the very marked improvement in the character of the filtered water when the solution pump had been repaired. The number of bacteria in the filtered water decreased immediately from 2,200 to 130 per c. c. when the alum was properly applied, and there was also a very rapid decrease in the turbidity. On November 20th, although the bacterial content of the river increased, the number in the filtered water averaged but 100, due primarily to a regular application of the coagulant. These results indicate that the efficiency of the filter depends upon a regular and constant application of alum. At this examination it was suggested that new tanks be provided for the preparation of the coagulant solution, and two new tanks, as have been described, were installed in the winter of 1907. These have permitted a much more constant application of the coagulant, and, also the rate at which the solution is applied is more easily observed by the engineer.

As the filter is but 8 feet in diameter, and contains two feet of concrete and four feet of filtering material, there remains but two feet of space available for the storage and coagulation of the applied water. The capacity of this space is but 1,800 gallons, and at the usual rate of pumping, 330 gallons per minute, the actual time allowed for coagulation is but 6 minutes. At the first examination it was appreciated that the time allowed for the coagulation was too short to permit a complete chemical reaction and that much better results would obtain if the point of application of the solution were changed from the inlet of the filter to that of the settling basin. The storage in the latter would provide a period of 9¾ hours for sedimentation and it is reasonable to suppose that this would increase the bacterial efficiency of the basin to about 90 per cent. with one grain of coagulant per gallon. This change would result in the use of less coagulant and wash water, and, what is of the greatest importance, would insure better results in bacterial removal and a better quality of filtered water.

Settling Tank.

In order to determine the bacterial reduction in the water applied to the filter, it is necessary to shut down the plant in order to obtain a sample of settled water, and this was done on but one examination, that of July 24th, 1906. It was then found that the raw water contained 10,000 bacteria per c. c. and had a turbidity of 1,000 parts per million. The water applied to the filter had a turbidity of 800 parts per million and contained 4,700 bacteria per c. c., while a sample obtained from the top of the settling basin had a turbidity of 500 parts per million and contained 1,500 bacteria per c. c. These results indicate

that there might have been a removal of 85 per cent. of the bacteria and 50 per cent. of the suspended matter by the tank. From the fact that the applied water was obtained from near the bottom of the tank rather than from the top, there resulted a removal of but 50 per cent. of the bacteria and but 20 per cent. of the suspended matter. On the subsequent examinations, the analyses indicate that the water at the top of the tank had a turbidity but 40 per cent. as great as that in the river. In other words, during the special investigation there has been a removal by the settling basin of but 20 per cent. of the turbidity in the river water, while had the floating outlet from the basin been used, there should have resulted an average removal of 60 per cent. of the turbidity. The water as applied to the filter has been approximately twice as turbid as would have been the case had the floating outlet been in repair.

Had the point of application of the alum been changed to the inlet of the settling basin, it is reasonable to suppose that the efficiency of the basin would have been increased to 90 per cent., particularly at times of high turbidity in the river water. This would have resulted in a marked increase in the economy of operation of the plant. Not only would less wash water and shorter hours of operation have been necessary, but there would have resulted a marked improvement in the character of the filtered water.

Filter.

Contrary to the condition that maintains with an ordinary mechanical filter plant, it has been observed that the best efficiency of removal by the pressure filter obtains immediately after washing, and that there is a decrease in the quality of the effluent as the run increases. This condition maintains until the point is reached where the effluent is quite turbid, and it is then necessary to wash the filter.

During the examination of July 24th, 1906, the river was very muddy and the effluent from the filter contained considerable suspended matter, while the bacterial removal averaged but 90 per cent. On November 19th, 1906, the river was clear, but very poor results were obtained by the filter during the first part of the examination from the fact that no coagulant was being used. When the latter was properly applied, however, the filtered water was of very good quality. On May 16th, 1907, the removal by the filter was again only 90 per cent. but the supply was practically clear and colorless, and although coli were found in the river, occasionally in considerable numbers, yet there were contained in but two samples of filtered water, and then only in 100 c. c. portions.

It is apparent that the efficiency of the filter depends largely upon the proper preparation of the applied water. During the first two examinations the filter was operated at excessive rates which, especially during such times as the river was turbid, caused a poor quality of filtered water.

A review of the evidence obtained during the various investigations shows that the filtered water frequently is quite turbid, and contains large numbers of bacteria, yet the absence of coli would indicate that it was potable. Fortunately, there is no near source of pollution above the Pomeroy waterworks.

REVIEW OF EFFICIENCY OF PLANT DURING SPECIAL INVESTIGATION.

During the special investigation it has been shown that the water supply for Pomeroy is frequently quite turbid and contains larger numbers of bacteria than is considered desirable. From the fact that there is no dangerous pollution of the Ohio River within 60 miles, and that no evidence of recent contamination has been found in the water of the river, except on one examination,

the Pomeroy supply, is considered potable, although frequently of undesirable appearance. Several features which have contributed to the poor results obtained may be summarized as follows:

First — The operation of the filter at too great a rate.

Second — The use of too small quantities of coagulant, applied irregularly.

Third — The incorrect use of the coagulant and the short period allowed for its chemical reaction.

Fourth — The incorrect use of the settling basin and its discharge from near the bottom rather than from near the top.

Of the above features, there is but one the elimination of which would increase the expense of maintenance, and that is the operation of the filter at a decreased rate. This would require either longer hours of service or the installation of a new unit. The former would increase the cost of labor, and the latter would require a new filter, and probably also a new pump. The changes in the use of the coagulant have been suggested at various examinations, but it is apparent that their value is not appreciated, a fact which has resulted in unnecessarily long hours of operation, and the use of large quantities of wash water.

COST OF INSTALLATION.

The cost of installation of the water purification plant of the Pomeroy & Middleport Water Company is shown in the following table:

INTAKE		$290
PUMPS		4,025
BOILERS		1,694
BUILDING		5,903
Land	$900	
Building	4,632	
Extra Work	371	
FILTER		3,500
SETTLING BASIN		3,482
Land	$500	
Settling Tank	2,982	
TOTAL COST		$18,895

COST OF OPERATION — 1906.

In the following table is shown the actual expenses incident to operating the Pomeroy water plant. These do not include the fixed charges, taxes, insurance and interest.

SALARIES		$1,524
Superintendent	$75 per mo.	
1 Engineer	65 " "	
1 Assistant Engineer	50 " "	
Office Assistants	556 " yr.	
LABOR ON DISTRIBUTION SYSTEM		437
COAL, 694 tons at $1.25 per ton		868
ALUM, 24 barrels		56
INCIDENTALS		1,653
TOTAL COST OF OPERATION		$4,538
Approximate total number of gallons pumped		94,900,000
Approximate total cost per million gallons		$47.83

TABLE NO. 37.

Pomeroy — Record of Operation.

Month.	Average Hours of Operation.	Gallons Water Filtered.	Rate of Filtration M. G. P. A. P. D.	*Wash Water		Coagulants		Turbidity	
				No. Washes.	Per cent. Wash-water.	Lbs.	Gr. P. Gal.	River.	Effluent.
1907.									
January	10	188,000	136	3	26	67	2.4	675	90
February	9	191,000	154	3	25	44	1.6	625	90
Average	9.5	190,000	145	3	25.5	56	2.0	650	90
July	16	325,000	147	5	25	51	1.1	1,100	70
August	17	349,000	149	5	23	62	1.2	950	65
September	17	334,000	142	4	19	61	1.2	800	65
Average	16.7	336,000	146	4.7	22	58	1.2	950	65

* Use approximately 16,000 gallons of water per wash.

TABLE NO. 38.

Pomeroy — Results of Analyses During Examinations.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	
	1906	A. M.								
273	7-24	9:10	Raw water	9,800	0	0	0	1000	45	.....
		P. M.								
279	7-24	2:00	Raw water	28,400	0	0	.....	1000	52	.....
			Average	19,100	.....	.....	.....	1000	49	.....
		A. M.								
274	7-24	10:15	Set. water (applied to filter)	4,700	.....	.....	800	.....	.....	.....
275	7-24	10:30	Set. water (top of tank)...	1,500	.....	.....	500	.....	.....	.....
272	7-24	9:00	Filtered water at pump.....	1,300	.....	.....	0	40	42	.....
276	7-24	11:00	Filtered water at pump (before washing)	4,500	.....	.....	.....	150	.....	.....
277	7-24	11:23	Filtered water at pump (after washing)	900	0	0	.....	75	.....	.....
		P. M.								
278	7-24	1:45	Filtered water at pump.....	2,200	0	0	.....	200	42	.....
280	7-24	2:58	Filtered water at pump.....	1,000	.....	.....	.....	110	.....	.....
283	7-24	4:30	Filtered water at pump.....	1,400	0	0	.....	40	42	.....
			Average	1,900	.....	.....	.....	100	42	.....
281	7-24	3:35	Reservoir	800	0	0	.....	30	43	.....
282	7-24	3:50	Horse trough on 2d street..	1,800	.....	.....	.....	.....	.....	.....
		A. M.								
308	11-19	8:30	Raw water	12,500	0	0	30	30	40	.....
		P. M.								
313	11-19	2:00	Raw water	3,800	0	0	30	30	40	.....
			Average	8,200	0	0	30	30	40	.....

TABLE NO. 38 — Concluded.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Incr.
		A. M.								
807	11-19	8:30	Filter effluent	1,500	0	0	30	5±	40	.....
809	11-19	9:30	Filtered water, bottom of filter	2,200	0	+	20	20	40	.....
810	11-19	10:00	Filter effluent at pump	3,500	0	0	25	5	40	.....
		P. M.								
812	11-19	1:00	Filter effluent at pump	130	0	0	15	5—	31	.....
814	11-19	2:30	Filtered water, bottom of filter	210	.....	.....	15	5—	31	.....
816	11-19	3:30	Filter effluent at pump	425	0	0	55[2]	5—	31	.....
			Average	1,300	.....	.....	27	8	35	.....
811	11-19	12:30	Tap at Remington Hotel	1,200	0	0	15	5+	38	.....
815	11-19	3:00	Settled water, top of basin.	9,400	.....	.....	.....	20	40	.....
	1906	A. M.								
819	11-20	7:30	Raw water[1]	16,500	0	0	25	250	41	.....
823	11-20	11:00	Raw water	14,500	0	0	35	250	41	.....
			Average	15,500	.....	.....	30	250	41	.....
818	11-20	7:00	Filter effluent at pump	170	0	0	15	5—	36	.....
820	11-20	8:38	Filter effluent at pump	85	.....	.....	10	5—	21	.....
821	11:20	9:00	Filter effluent at pump	95	.....	.....	10	5—	.....	.....
824	11-20	11:30	Filter effluent at pump	43	0	0	10	<5	24	.....
			Average	98	.....	.....	11	5	27	.....
822	11-20	10:00	Settled water, top of basin.	3,800	.....	.....	35	70	40	.....
817	11-20	6:30	Tap at Remington Hotel	375	0	0	30[2]	5+	36	.....
	1907	A. M.								
1309	5-16	9:00	Raw water	4,600	+	+	10	120	27	10
1313	5-16	11:00	Raw water	4,100	0	+	.....	110	27	.....
		P. M.								
1319	5-16	4:00	Raw water	5,500	0	0	.....	85	28	.....
		A. M.								
1310	5-16	9:30	Settled water, top of basin.	5,500	0	+	.....	45	27	.....
1308	5-16	8:30	Filtered water at pump	825	0	0	4	<5	21	.....
1311	5-16	10:00	Filtered water at pump	290	0	+	4	<5	20	.....
1312	5-16	10:55	Filtered water at pump	330	0	0	6	5±	20	.....
		M.								
1314	5-16	12:00	Filtered water at pump	375	0	0	4	<5	20	.....
		P. M.								
1316	5-16	1:30	Filtered water at pump	345	0	0	4	<5	19	.....
1318	5-16	3:30	Filtered water at pump	220	0	0	4	<5	22	.....
1320	5-16	5:00	Filtered water at pump	450	0	0	4	<5	20	35
			Average	400	.....	.....	4	<5	20	35
1317	5-16	3:00	Reservoir	375	0	+	10	5±	24	34
1315	5-16	1:00	Tap at Remington Hotel	550	0	0	8	5±	22	30

[1] Heavy rain all night; river rose 6 feet during night.
[2] On unfiltered sample.
CO_2. Samp. No. 1313, 3; Samp. 1312, 5; Samp. No. 1316, 5; Samp. 1315, 7.

ROCKY RIVER.

The village of Rocky River is in the northern part of Ohio in Cuyahoga County, near Cleveland, on the Rocky River, about one-half mile above its point of discharge into Lake Erie. It contains no manufacturies, and is a residential town. Its population is estimated at 1,300.

HISTORICAL

The waterworks were installed in 1906 during the special investigation by the State Board of Health, and the source of supply was the Rocky River. This has a watershed above the village of 340 square miles on which there is a total population of 15,000, or 72 per square mile, contained in more than ten small communities. With the exception of Lakewood, which is located at the mouth of the river opposite Rocky River and has a population of about 10,000, none of these small communities contain more than 4,000 people, nor do they have any municipal system of sanitary sewers. The sewage from Lakewood, however, is carried to a disposal plant about one-half mile above the intake of the Rocky River water supply, where about 1,000,000 gallons of sewage per day are treated. Although this plant has given very satisfactory results from a chemical standpoint during the special investigation by the State Board of Health, at times there is a considerable quantity of sewage by-passed, and probably also the plant does not accomplish a very high efficiency of bacterial removal.

At Rocky River, also, all of the surface drainage enters the river above the waterworks intake, and there is also reason to believe that a considerable quantity of house drainage enters some of the storm water sewers.

In general it may be said that the water of the Rocky River near its mouth contains considerable sewage and at times carries large amounts of suspended matter. It is entirely unfit for use as a domestic supply without purification.

DESCRIPTION OF PLANT.

The waterworks built by the Rocky River Water, Light & Power Company, comprise an intake in the Rocky River; low and high service pumps; a gravity mechanical filter; a clear well; a coagulating basin with the necessary appurtenances; a steel stand-pipe for the storage of filtered water, and a distributing system.

The pumping plant, together with the filter and clear well, are contained in a substantial brick building, located on the west bank of the Rocky River, just below the village. (See Plate XVII.)

Intake and Raw Water Pump.

It is eventually the intention of the water company to take its supply from Lake Erie. It is expected that a new channel will be dredged down the Rocky River to Lake Erie during the ensuing year, after which time the intake for the waterworks will be laid down this channel about 3 feet below the bottom. The construction of such an intake at the present time would involve considerably greater expense than after the above channel has been completed, as it would be necessary to dredge a trench about 25 feet deep, whereas in the future but 3 feet of excavation will be required. For this reason a temporary intake was constructed, and the use of the river water will be continued until such time as a new intake using Lake Erie water can be installed.

The temporary intake is a concrete structure 7′ wide x 9′ long x 10′ deep, and contains a vertical screen 6′ x 4′, of ½-inch round rods, one inch center to

center. It is located just below the bridge of the Nickel-Plate Railroad, and on the bank of the river.

From the intake a 12-inch cast iron suction 60' long leads to the low service pump, which is of the compound duplex type, and has a capacity of 750,000 gallons per day. This pump forces the water to the settling tank and has a total lift of 37 feet.

Coagulating System.

Coagulant. The coagulant used is the Natrona brand of aluminum sulphate, obtained from the Pennsylvania Salt Manufacturing Company of Philadelphia, Pa.

Means for Applying Coagulant. For the preparation and storage of the coagulant solution, a wooden tank 3 feet in diameter by 3.5 feet high is provided, which has a capacity of 185 gallons. From this tank the solution is carried through a small lead pipe and introduced into the main near the raw water pump. The only method of control originally provided was a globe valve in the solution line and the rate of application was indicated by a glass gage in the side of the tank. As this method was not found efficient at examinations made during this investigation, a 1" x 4" pump was provided which is directly attached to the raw water pump and forces the solution into the main leading to the coagulating basin at a rate varying with the speed of the low service pump.

Coagulating Basin. For the preliminary treatment of the water, a wooden tank is provided 24 feet in diameter with 18 foot staves and holding 50,000 gallons. It is well baffled with three wooden partitions, and at the ordinary rate of pumping, 500,000 gallons per day, the storage available is about 2½ hours. The top of the tank is about 16 feet above the top of the filter, to which the water is conveyed by gravity. The height of the water in the basin is controlled by a float valve in the inlet, and a Fisher automatic pressure governor at the pump. The discharge from the basin is through a stand-pipe, the top of which is about 4 feet below the top of the tank.

Filter.

The filter consists of a wooden tank 15 feet in diameter, and has a guaranteed capacity of 500,000 gallons per day.

The strainer system consists of a large number of brass perforated screens, screwed at 6-inch intervals into a manifold of wrought iron pipes. The filtering material rests on the strainer system, and consists of 30 inches of sand obtained from Cape May, N. J. It has an effective size of 0.36 m. m. and a uniformity coefficient of 1.5.

The filter is washed by a reverse current of water obtained directly from the mains, and the dirty water is removed by an annular trough built around the inside of the filter. To assist in washing, mechanical rakes are provided consisting of steel rods extending about 2 feet into the sand.

No loss of head gages nor automatic rate controllers are provided, and the only method of regulating the rate of filtration is by the setting of a valve in the effluent pipe.

Storage of Filtered Water.

Clear Well. The effluent from the filter discharges into the clear well, which is contained within the foundation walls of the filter house. It has a depth of 7 feet and a capacity of 13,500 gallons. At 750,000 gallons per day the length of the storage period provided is 39 minutes. The total available head on the filter is 9 feet.

High Service Pump. From the clear well the water is pumped to the stand-

pipe by a Worthington compound duplex pump, which has a nominal capacity of 1,500,000 gallons per day, and pumps against a pressure of 103 pounds.

Stand Pipe. For the storage of filtered water, a steel stand-pipe was built 1½ miles from the pumping station. It has a diameter of 15 feet and a height of 100 feet with a capacity of 132,000 gallons and is at such a height that the pressure maintained in the mains in the central part of the village is 80 pounds.

EXAMINATIONS.

The plant of the Rocky River Water, Light & Power Company has been visited four times during 1907, as follows: February 8th, March (17-20), July 26 and December 13. On the first and last of these dates, the works were merely inspected but on March 17 and July 26, regular examinations were made and samples collected and analyzed. The examinations were of special value because the plant had not been accepted by the water company, and it was necessary to first show that it was capable of giving satisfactory results. The examination of July 26th was practically an official test of the plant and a representative of the filter company was present.

OPERATION.

As the average daily consumption at Rock River is about 50,000 gallons and the plant has a capacity of 500,000 daily, it is customary to pump but 8 hours a week. An engineer is employed on a monthly basis, and as it is customary to operate the plant but three days out of the week, this fact tends to increase the cost of operation and also the difficulty of obtaining the best bacterial removal by the plant.

When operating the plant, the coagulating basin is first filled with river water into which the coagulant has been introduced, and then its contents are run through the filter which has previously been washed. When the clear well is nearly full, the high pressure pump is started and the operation of the plant is then continued until a sufficient supply has been furnished.

Coagulating System.

The coagulant is mixed in charges of 50 pounds, which is placed in a perforated box in the top of the solution tank. Water is then run through this box into the storage tank. The actual quantity of coagulant applied is generally about 2 grains per gallon, and is varied by changing either the strength of the solution or the length of the stroke of the feed pump.

The coagulation or sedimentation tank requires but little attention, as it serves merely as a storage to allow for the completion of the chemical reaction, and the deposition of the heavier particles of suspended matter. The controlling features that regulate the depth of water in the basin have always proven very satisfactory — in fact the governor on the pump has been found very efficient without the float valve. The latter was removed when ice formed in the tank.

Filter.

As no automatic rate controller nor loss of head gage is provided for the filter, it is necessary for the engineer to determine both when the filter is operating at a satisfactory rate and when washing is necessary. It was found during the examinations that the rate of filtration varied considerably but without apparent effect on the bacterial removal obtained.

In order to avoid bacterial growth in the sand it is generally the custom

to wash the filter, either before starting in operation or at the completion of each day's run, on which account the percentage of wash water is unusually high. The rate of application of the wash water has been found to vary considerably, and although the gutter is flooded when the rate is greater than 6 inches per minute, the average rate of application is about 9 inches per minute for 10 minutes, which gives 7.5 vertical feet per wash, corresponding to 9,900 gallons. This quantity is greater than would be the case if better facilities had been provided for the removal of the dirty water.

CHARACTER OF RAW WATER.

On the examination of March 18, there was considerable variation in the quality of the raw water, particularly in its bacterial content and turbidity. This was in part due to fluctuations in the flow of the river caused by the transverse seiches in the water of Lake Erie. According to the engineer at the plant, these seiches occur approximately every 20 minutes, and at times a decided current from the lake up the river was noted. The river water contains but little dissolved color and comparatively large amounts of suspended matter.

During the examination of July 26, the suspended matter and bacterial content were less than on March 18, but coli were present in 1 c. c. of each sample taken. The flow in the river was less than on the previous examination and as would be expected the water was found considerably harder.

From the evidence obtained by the analyses, it will be seen that the water treated by the Rocky River plant generally is badly polluted and subject to rapid changes, on which account it requires the best possible efficiency of bacterial removal and constant watchfulness on the part of the operator.

GUARANTEE FOR FILTER.

The contract with the filter company contains the following guarantee:

"That the filter shall be guaranteed to deliver 500,000 gallons of water every day of 24 hours.

"That the filtered water shall be clean and clear and practically free from suspended matters and turbidity visible to the naked eye.

"That when the number of bacteria in the unfiltered water is 3,000 or more per c. c., there shall be a bacterial reduction in the filtered water averaging not less than 97 per cent. and that when the number of bacteria in the unfiltered water is less than 3,000 per c. c., the average of bacteria in the filtered water shall not exceed 100 per c. c."

EFFICIENCY OF PLANT DURING EXAMINATIONS.

The methods of operating the plant were very similar during both examinations, and the results obtained will be discussed together. The following is a statement of the bacterial removals:

By the coagulating basin, 63% and 79%.

By the filter, 64% of the bacteria in the applied water which gives a total removal by the plant of 87% and 93% of the bacteria in the river water.

The analyses indicate considerable variation in the quantity of alum applied and that the efficiency obtained by the basin and the filter increased with the larger amounts of coagulant. There was an increase in the efficiency of the coagulating basin with the length of operation of the plant.

These results indicate that the purification is about equally divided between the coagulating basin and the filter and that the final product is largely influenced by the percentage removal obtained by the basin. The work done by the filter was not satisfactory and it is probable that the throttling necessary to

destroy the head between the basin and the filter and the consequent breaking up of the coagulated masses in the water applied to the latter had a considerable influence in the final efficiency of the plant. The fluctuations in the quantity of coagulant applied also had a considerable influence on the results obtained.

CHARACTER OF FILTERED WATER.

As would be expected from the character of the river water, unless there is a high degree of purification by the plant, a considerable unmber of coli are left in the effluent from the filter. The bacterial analyses during both examinations indicate the presence of coli throughout the plant; on the examination of March 18, there were also a large number of bacteria in the filtered water. On the examination of July 26, although the total number of bacteria in the filtered water was less than 100 per c. c., the fact that coli were always present and sometimes in considerable numbers would indicate that the filtered water was not potable.

CHANGES DURING SPECIAL INVESTIGATION.

The alum regulating devices were not satisfactory at either examination and the superintendent was so advised. In the fall of 1907, the gravity method of control for applying the coagulant solution was changed and the alum was forced by a small pump directly into the raw water main at a rate varying approximately with that at which the water was pumped to the coagulating basin. This method of application has proven very satisfactory and should materially assist in the ease of operating the plant, as it requires but little attention on the part of the operator. The water company has notified the filter company that the coagulating basin must be lowered until nearly at the same height as the filter and it is probable that this will soon be done. When these changes are completed there should be no difficulty in obtaining a much more satisfactory effluent from the filter.

After the official test of July 26, the water company was notified that although the filter was apparently capable of doing satisfactory work at that time, yet the raw water was so highly polluted that the effluent from the filter, although within the guarantee furnished by the filter company, was still unpotable. They were advised by the State Board of Health that it would be impossible to obtain a satisfactory water from Rocky River with their present plant and that their source of supply should be changed from the river to Lake Erie. It is the intention of the water company to construct a new intake in Lake Erie at a point about 1,400 feet to the northwest of the mouth of the Rocky River, a change which will probably be made during the early part of 1908.

The following tables show the cost of installation and operation of the Rocky River plant:

COST OF INSTALLATION.

Real estate		$10,650
Expense account		3,148
Pump house, (including intake)		7,404
Machinery		10,274
Pumps, boilers, engine for agitator	$7,310	
Filter and coagulating system	2,750	
Tools	214	
Pipes (distributing system)		14,029
Labor		10,472
Includes pipe laying, foundation of standpipe, extra labor at plant.		

Standpipe	3,619
Meters	385
Total cost	$59,981

COST OF OPERATION.

Labor	$780 00
1 engineer ..... $65.00 per mo.	
Supplies	240 00
Coal, $3.00 per ton $216 00	
Coagulant, 1.25 cts per lb 24 00	
Total cost	$1,020 00

Average daily consumption, 50,000 gallons....18,250,000 G. P. Year
Average cost per million gallons.....$56.00. (Operation only).

TABLE NO. 39.

Rocky River — Results of Analyses During Examinations.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	CO_2.
	1907	P. M.								
1109	3-18	2:45	Raw water	5,000	0	0	10	120	50	.....
		A. M.								
1112	3-19	9:15	Raw water	8,900	0	0	10	90	52	.....
		P. M.								
1118	3-19	2:00	Raw water	7,200	+	+	12	120	52	.....
1110	3-18	4:00	Settled water, top of filter..	3,500	.....	.....	.....	.....	46	.....
		A. M.								
1114	3-19	11:00	Settled water, top of filter..	3,800	+	+	.....	45	38	.....
		P. M.								
1116	3-19	2:00	Settled water, top of filter..	1,700	0	0	.....	40	27	.....
1120	3-19	4:30	Settled water, top of filter..	2,100	+	+	.....	.....	33	.....
1111	3-18	4:00	Filter effluent	1,860	0	0	10	<5	50	.....
		A. M.								
1113	3-19	11:00	Filter effluent	1,400	0	+	4	<5	40	.....
		M.								
1115	3-19	12:00	Filter effluent	800	0	+	4	<5	32	.....
		P. M.								
1117	3-19	2:00	Filter effluent	425	0	0	2	<5	26	.....
1119	3-19	3:15	Filter effluent	180	0	+	4	<5	27	.....
1121	3-19	4:30	Filter effluent	900	0	+	4	<5	31	.....
	1907	A. M.								
1545	7-26	8:30	Raw water	950	+	+	15	80	105	5
1549	7-26	11:30	Raw water	450	+	+	.....	85	110	4.5
			Average	700	.....	.....	15	82	108	5
1546	7-26	9:00	Settled water, top of filter.	250	0	+	.....	35	89	21
1550	7-26	11:30	Settled water, top of filter.	110	0	+	.....	20	86	20
		P. M.								
1552	7-26	2:00	Settled water, top of filter.	80	0	0	.....	21	83	.....
			Average	147	.....	.....	.....	25	86	20.5
		A. M.								
1547	7-26	9:30	Filter effluent*	80	0	+	5	<5	89	17
1548	7-26	11:15	Filter effluent	55	0	+	5	<5	84	16
		P. M.								
1551	7-26	1:00	Filter effluent	31	+	+	5	<5	82	.....
1553	7-26	2:00	Filter effluent	40	0	+	3	<5	72	23
			Average	52	.....	.....	5	<5	82	19

*Rate of filtration — million gallons per acre per day, at 11:15 A. M. = 78; at 1 P. M. = 195; at 2 P. M. = 119.

Incrustants, Samp. No. 1118 = 76; Samp. No. 1119 = 128; Samp. No. 1121 = 114.

UPPER SANDUSKY.

Upper Sandusky, the county seat of Wyandotte County, is in the north central part of Ohio on the Sandusky River. Its population was estimated in 1906 at about 4,500. The village is in the center of a farming district, and contains several small manufactures.

HISTORICAL.

Several different methods have been employed for obtaining the water supply for Upper Sandusky, which, briefly stated, are as follows: The original source was a large dug well near the Sandusky River from which a supply of ground water was obtained. This failed, as it was found impossible to obtain a sufficient quantity of water and the supply was then taken from the river, settled in a large open basin, and filtered through a "filter box," the effluent of which was collected in the original open well, the use of which was continued. This method also failed to give a sufficient quantity of water, and the supply was then taken from the river and treated in a mechanical filter plant which is now in successful operation.

Original Installation.

The original waterworks were built in 1889 and were located on the banks of the Sandusky River about one-half mile above the center of the village. They comprised a large open well, pumps and machinery housed in a substantial brick building, a stand-pipe, and a distributing system. The source of the supply was a large open well, 85 feet in diameter at the top and 12 feet deep. Its sides were paved with rough stones. The water obtained was from ground sources, although it was thought that perhaps some was obtained also by infiltration from the river. It was lifted by two duplex Blake pumps, of 1,500,000 gallons capacity each, to a stand-pipe which consisted of a wooden tank 24 feet high by 28 feet in diameter, holding 95,000 gallons, and which was erected on a circular brick tower 75 feet high.

As it was found impossible to obtain a sufficient quantity of ground water from the well, in 1902 the superintendent of the waterworks built a purification plant of his own design, by which the supply was taken from the river into a large settling basin from which it flowed horizontally through a filter box into the well used as the original source.

The settling basin was excavated near the river, from which it was separated by an earthen dike, and at such a depth that it received water from the river by gravity. It was 325 feet by 180 feet, with a storage capacity of 230,000 gallons. At the outlet of the basin was constructed a filter box, 20 feet by 11 feet, and containing 3 feet of fine gravel. When in use, the filter was cleaned once a month by scraping the top, and also twice a year by removing and washing all the gravel. As might be expected, it was found impossible to obtain sufficient water, and it was frequently necessary to bi-pass the "filter" and use water from the Sandusky River without purification.

Conditions Requiring Purification.

The Sandusky River, with a drainage area of 285 square miles above the waterworks, flows through rolling land, used largely for pasturage of hogs and cattle. There are no villages on the watershed nearer than Bucyrus, which is 24 miles above the intake, and has a population of 6,600. The sewage of Bucyrus is discharged directly into the river without purification.

The water supply of Upper Sandusky was examined by the chemist of the State Board of Health on seven occasions during 1904, and in his report of these examinations it was stated that the "water is in no wise acceptable, but that it is objectionally hard, is displeasing in appearance, carries much organic matter, and at times gives evidence of sufficient sewage pollution to class it as a suspicious water."

It was for the improvement of the appearance of the supply, and also for the removal of pollution, that a mechanical filtration plant was installed by the Upper Sandusky Water Company in 1905.

DESCRIPTION OF PLANT.

During the special investigagtion by the State Board of Health, the plant has included several of the earlier features, and comprised a low crib dam, low and high service pumps, two coagulating tanks, two gravity mechanical filters, a clear well, and a stand-pipe for the storage of filtered water.

Intake and Raw Water Pump.

When the "filter box" was installed, a low crib dam was built opposite the pumping station, by which about 500,000 gallons is impounded during low water stages of the river. The present intake is just above this dam and consists of a cast iron pipe laid directly on the bottom of the river. This pipe is about 100 feet long, and terminates in a small well containing the suction of the low service pump. The latter is of the centrifugal type and has a rated capacity of about 1,000,000 gallons per day.

Coagulating System.

Coagulant. The coagulant used is a standard brand of aluminum sulphate, obtained from the Pennsylvania Salt Manufacturing Company of Philadelphia, Pa.

Solution Tanks. The alum is dissolved in two small wooden tanks, each 4.5 feet deep by 2 feet 2 inches in diameter, holding 500 gallons.

Means For Application. At the beginning of the special investigation, the coagulant solution was carried by a small pipe and discharged into the first coagulating tank at the inlet. Its rate of application was governed by a globe valve. As this apparatus was found to be very inefficient, in January, 1907, the solution pipe was changed to 1¼-inch wrought iron, and a ball-cock tank was provided for the regulation of the rate of application of the solution. This tank serves to maintain a constant pressure on the regulating valve, the use of which is continued.

Coagulation and Sedimentation Tanks. The raw water is pumped directly from the river into the coagulating tanks, which comprise two wooden tubs, one, 14 feet in diameter, and one, 14½ feet in diameter, and both with an available depth of 11 feet. The total capacity of the tanks is 26,260 gallons, which gives a coagulating period of one hour at the usual rate of operation. The tanks are well baffled by two vertical partitions, and their tops are approximately 5 feet above the tops of the filters, onto which the coagulated water flows by gravity.

Filters.

Capacity. The filter plant comprises two wooden tanks, built by the Pittsburg Filter Manufacturing Company, each 12 feet in diameter with a total area of 226 square feet, or .00519 acre. The guaranteed capacity of the filter plant

is 500,000 gallons in 24 hours, corresponding to an average rate of 96,000,000 gallons per acre per day.

Strainer System. The strainer or collecting system consists of cast iron cups covered with perforated brass strainers and fastened to a false bottom of wood. They are about 18 inches apart.

Filtering Material. The filtering material consists of 4 feet of sand obtained from Norcross & Edmunds of Birmingham, N. J., and has an effective size of .49 m. m. and a uniformity coefficient of 1.5. Twelve inches of unscreened gravel was placed over the strainer system.

Washing System. The filters are washed by a reverse current of water obtained directly from the force main, and the dirty wash water is carried away by annular metallic troughs, 6.5 inches wide by 17 inches deep. The sides of the gutters have been raised during the special investigation, and they are now ample for the removal of the water used. Mechanical rakes are provided to assist in washing.

Automatic Devices. No loss of head gages, nor effluent rate controllers are provided, and the only means for governing the rate of filtration are the valves in the discharge pipe of the filters.

Storage of Filtered Water.

The effluent from the filters flows by gravity to the clear well, for which the old dug well is used. This was relined with concrete paving in 1903, although the bottom has not been covered and consists of the original rock. The well has an average diameter of approximately 50 feet, is 10 feet deep and has a total capacity of 147,000 gallons. Concrete piers were provided for a covering for the clear well if found necessary, but have been removed, and although there is a considerable growth of sponge in the well during the warm seasons, it has never been covered.

As the well is unsealed, there is a considerable seapage of ground water into it, which materially effects the quality of the water furnished, as the ground water is very much harder than that in the river.

The available head on the filters when the clear well is full is very nearly 30 feet.

Stand-pipe. For fire protection and equalization of the consumption, a steel stand-pipe is provided, which is located about 500 feet from the pump house on the force main to the village. It is a covered steel tank, and has a capacity of 100,000 gallons.

High Service Pumps. A triplex power pump of 750,000 gallons capacity is provided to lift the water from the clear well to the stand-pipe. The pump is driven by a 50 H. P. gas engine, using natural gas as fuel. The engine also drives the raw water pump and the agitators used in washing the filters.

EXAMINATIONS.

During the special investigation by the State Board of Health, the plant of the Upper Sandusky Water Company has been visited five times, on June (6-7), September (19-21), 1906, January (9-10), February 21st, and July (1-2), 1907. Regular examinations were made on each of the above visits, except on February 21st, 1907, when the plant was inspected.

OPERATION.

In operating the Upper Sandusky plant, water is pumped from the river to the coagulating tanks at the entrance of which the coagulant solution is in-

troduced. From the coagulating tanks, the water flows by gravity through the filters into the clear well, and is pumped by the high service pump into the stand-pipe. The daily operation of the plant generally covers a period of about 11 hours, and is in charge of one engineer. It has been impossible to obtain complete daily records of the plant during the special investigation, and the only records available are shown in Table No. 40.

Average Daily Consumption.

The available records cover a period of five months during 1907, and indicate a considerable seasonal variation. The average daily consumption, as shown on the records, is 272,000 gallons, but it is apparent that this figure is in excess of the average consumption for the year, which is probably very nearly 260,000 gallons per day.

The use of the ground water flowing into the clear well has been continued since the filter plant was installed, so that the total consumption includes partly the effluent from the filters and partly water from ground sources. It has been difficult to measure accurately the quantity of seapage into the well, but it was stated by the engineer that the rise in the well over night, during a period of approximately 8 hours, when the filter plant is idle, is very nearly 1.25 feet. This corresponds to approximately 40,000 gallons per day, a quantity which has been subtracted from the average daily consumption in estimating the number of gallons actually filtered as shown in the daily records. During high stages of the river, the maximum quantity of the seapage is about one and one-half times the average, or 60,000 gallons per day.

TABLE NO. 40.

Upper Sandusky — Record of Operation.

Month.	Average Daily Consumption.	Number Hours in Service.	Gallons Filtered (Est.)*	Wash Water†		Coagulant		Turb.
				Gallons.	Per cent.	Lbs.	Gr. p. Gal.	Raw Water.
1907.								
April	244,000	11.6	204,000	9,200	4.5	73	2.5	200
May	259,000	11.2	219,000	9,200	4.2	88	2.8	230
June	275,000	10.9	235,000	8,500	3.6	88	2.6	.....
July	300,000	11.3	260,000	11,300	4.3	96	2.6	200
September	283,000	11.1	243,000	10,500	4.3	111	3.2	210
Average	272,000	11.2	232,000	9,740	4.2	91	2.7	210

* Seapage into clear well estimated at 40,000 gallons per day.

† Average rate of washing = 340 gallons per minute for 11 minutes, corresponding to 3,700 gallons per wash (4.4 vertical feet).

Method of Applying Coagulant.

At the beginning of the special investigation, the method of applying the coagulant was very crude, and the quantity used depended entirely on the judgment of the engineer. Although two solution tanks are provided, but one was used and it was the custom to occasionally add a pail of alum to the tank when deemed necessary. There was no regular application of the alum, and frequently the quantity used was not sufficient to produce the necessary coagulation. It was, moreover, necessary as the solution tank became empty, to open the regulating valve from time to time, and in general it may be said that the method of applying the coagulant was very unsatisfactory.

From recommendations during the first examination, the method of applying the coagulant was changed, and a definite quantity introduced in the solution tanks, which were used in turn. Following the third examination, a ballcock tank was provided for the better regulation of the application of the coagulant. The present method of application is to dissolve approximately 50 pounds of coagulant in a tank, and to continue the use of each tank in turn with a constant and regular application of the solution.

The average quantity of coagulant used, as shown in the daily records, is 2.7 grains per gallon.

Coagulating Tanks.

The use of the coagulating tanks requires little discussion. It is the custom to operate the raw water pump at a somewhat greater rate than is required to supply the filters, and the excess quantity pumped is wasted through an overflow in the first coagulating tank. The height of water on the filters to which the coagulated water flows by gravity is governed by float valves. The coagulating tanks are cleaned about once a month and there is generally removed from three to six feet of deposit from the first tank.

Filters.

Rate of Filtration. Numerous measurements of the rate of filtration have been taken during the examinations, and have shown considerable variations, which would be expected in the absence of automatic rate controllers. The rate at which the filters are operated is determined by the degree of opening of the valve on their effluent pipes, and it is generally the intention of the engineer to operate them at very nearly 125 million gallons per acre per day. The actual measurements obtained, however, show that the average rate is considerably less than the above figure, and is probably not far from 95 million gallons per acre per day.

Washing. The filters are washed by connections to the force main and the rate of application of the wash water depends on the degree of opening of the valves in these connections. Although it is intended to wash them at approximately a constant rate, from numerous measurements it has been observed that the rate of application varies from 3 to 7 inches vertical rise in the filter per minute. The average rate of washing is very nearly 340 gallons per minute for 11 minutes, corresponding to 4.4 vertical feet or 3,700 gallons.

From the location of the filter house at approximately the same level as the water in the river, considerable difficulty arises at times from the fact that it is impossible to drain the wash water from the filters into the river during times of high water. At such times the water in the river frequently rises to such a height that there is no head available to discharge the wash water, on which occasions the waste is discharged onto the floor below the filters, and

drains into the old settling basin. The rate of washing is then considerably decreased and the filters are cleaned less often than they should be.

Following the recommendations made during the examination of February 21st, 1907, the gutters in the filters have been raised about 8 inches in height, so that there is a free discharge over practically their entire length. This permits a more equal distribution of the wash water, as previously the gutters were submerged and the filter was more rapidly cleaned near the drain than at the back.

In general it may be said that the method of washing the filters has been very satisfactory, as the sand is well cleaned, and it will be seen from the daily records that the average quantity of wash water is but 4.2 per cent. of the quantity filtered.

CHARACTER OF RAW WATER.

The examinations of the Upper Sandusky plant have, with one exception, followed periods of continued fair weather, so that the results of the analyses obtained are representative of the ordinary conditions of the Sandusky River at the plant. The bacterial evidence shows the constant presence of pollution in the supply, as is indicated from the coli examinations. Coli have been found in the raw water during each examination, and frequently in considerable numbers. In the examination of July 1st, the river was low, and during this stage, coli were found in greater numbers than at any other time, a fact which would indicate that the pollution of the river is constant, and does not result from surface washing after heavy rains. Chemically, the water in the river is hard and contains such quantities of dissolved color and suspended matter as to render it of very unsatisfactory appearance and undesirable for domestic use.

The examination of January (9-10), 1907, followed a very heavy rain on January 8th, and the river then reached one of its highest stages. The crest of the rise had occurred before the beginning of the examination, as is indicated by the rapid decrease in turbidity, color and bacterial content, with the corresponding rise in alkalinity. Coli were found throughout the plant.

In general it may be said that the Sandusky River is very unsatisfactory for domestic use without purification, as it contains not only considerable suspended matter and color, but also sufficient pollution to make it unwholesome. Its satisfactory purification requires not only an improvement of its physical properties, but also an efficient removal of bacteria.

CHARACTER OF SEAPAGE INTO CLEAR WELL.

During the examination of September 20th, 1907, the clear well was drawn down in order to obtain a sample of the water that seaps into it through the bottom. When the well was re-lined several small pipes were embedded in the concrete during construction, in order to prevent ground water backing up on the concrete before it had set. These pipes had never been plugged and consequently, there is always considerable ground water flowing through them as well as through crevices in the rock forming the bottom. The discharge from some of the pipes had a distinct odor of sulphur, and was of disagreeable taste. Its analysis shows that it had a total hardness of 588 parts per million, while the river had a total hardness of but 284 parts per million; it also contained a considerable number of bacteria, although no coli were found. The addition of such considerable quantities of hard ground water, generally 40,000 gallons per day, causes an increase in the total hardness of the water supply at Upper Sandusky of about 33 per cent. This would suggest the advisability of its removal,

if possible, which could be accomplished in part by always maintaining the clear well as nearly full as possible. While there is probably no dangerous pollution of the supply by the ground water it causes a greater number of bacteria in the water in the clear well than in the effluent from the filters.

EFFICIENCIES.

Application of Coagulant.

At the beginning of the investigation the method of applying the coagulant was very crude and irregular, and the evidence indicates that the efficiency of the filters depends upon a constant application of alum. Variations in the rate of applying the coagulant are indicated by the considerable changes in the alkalinity of the filter effluents. The very poor results obtained by the plant on January 9th, 1907, were due largely to a poor application of the coagulant as, on the day previous to the examination, practically no alum had been applied owing to a stoppage of the solution pipes. Better efficiencies were immediately obtained from the filters when the alum was satisfactorily applied.

The present method of introducing the coagulant is very satisfactory, as it is possible to maintain its application at any desired rate.

During the examination of January 9th, 1907, the coagulant used was not so efficient as it should be. Analysis showed that it contained 17.62 per cent. of alumina of which 1.12 per cent. was in excess of that required to neutralize the sulphuric acid contained. Experimentally, it was learned that the alum did not give a rapid coagulation and a change of brand was recommended. Since that time the alum at Upper Sandusky has been obtained from the Pennsylvania Salt Manufacturing Company, and a sample taken in the fall of 1907 contained 20.53 per cent. alumina of which 4.48 was in excess of that required to neutralize the sulphuric acid. This brand of alum has been obtained at very nearly the same price, and has given much greater satisfaction.

Coagulating Basins.

Variable results have been obtained by the coagulating basins. On the examination of September 19th, 1906, there was a bacterial removal by the basins of 69 per cent. while two days later the removal by the basins was but 14 per cent. The turbidity determinations on July 1st, 1907, indicate that the water applied to the filters contained more suspended matter than that in the river. In general it may be said that the occasionally poor results obtained by the settling basins are due in part to the short period of sedimentation and in part to the partial breaking up of the coagulated masses in the applied water due to the throttling of the inlet valve to the filters.

Filters.

The examination of June (6-7), 1907, was the first that had been made by the State Board of Health since the filters were repaired, and was undertaken principally to determine their bacterial efficiencies. The evidence obtained at this examination indicates a very satisfactory removal by the filters. In the succeeding examinations there was considerable variation in the bacterial removals obtained, and most of the poor results were caused by inefficiencies in the methods of applying the coagulant. This was well shown on the examination of September 20th, 1906, when the alkalinity in the filtered water varied from 130 to 152 parts per million. The higher alkalinities indicate that practically no coagulant had been applied, and at such times there was a large increase in the numbers of bacteria in the filtered water.

REVIEW OF EFFICIENCY OF PLANT DURING SPECIAL INVESTIGATION.

The evidence obtained during the special investigation indicates that the raw water is always subject to pollution, and that the necessity for extreme care in the operation of the filter plant has not been appreciated by the operator, so that occasionally the water supply has been of unsatisfactory quality. There has, however, been a marked improvement in the character of the results obtained, and a desire on the part of the officials to co-operate with the State Board of Health in obtaining the best results. Although the river water and frequently the water pumped into the mains contains evidence of pollution, it should be stated that the supply has been found potable, as is indicated by the absence of typhoid fever among the consumers.

The water is objectionably hard for commercial use, and it might be considerable improved by sealing the clear well, and stopping the leakage of ground water. It is probable, however, that it would be very difficult to accomplish this as the concrete lining the well is of poor quality, and it would be difficult to make it impervious.

COSTS OF INSTALLATION AND OPERATION.

In Table No. 41 is shown the cost of installing the purification plant as now in use by the Upper Sandusky Water Company.

TABLE NO. 41.

Pumping plant		$8,800
Building	$5,000	
Gas engine	2,000	
Triplex power pump	1,800	
Filter plant		10,000
Building	$2,000	
Filters and appurtenances	8,000	
Stand-pipe, complete		4,000
Total cost		$22,800

In Table No. 42 is shown the estimated cost of operating the filter plant, together with the cost per million gallons. The interest charges shown are on the entire water works including original purification plant now abandoned.

TABLE NO. 42.

Labor (1 engineer @ $80 per month)		$960
Fuel ($0.25 per M. feet)		360
Coagulant ($21 per ton)		360
Interest and taxes		4,350
Total cost		$6,030
Total quantity of water pumped during 1907		95,000,000 gallons.
Average cost per million gallons		$63 50
Includes labor per million gallons	$10 10	
Fuel per million gallons	3 80	
Coagulant per million gallons	3 80	
Interest and taxes per million gallons	45 70	

TABLE NO. 43.

Upper Sandusky — Results of Analyses During Examinations.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Temp
	1906	A. M.								
1	6-6	8:05	Raw water	980	+	+	50[1]	70	182	21
4	6-6	10:00	Raw water	1,400	0	.....	55	60	.....	23
		P. M.								
7	6-6	1:00	Raw water	920	0	.....	50	50	170	26
10	6-6	3:30	Raw water	550	.....	.....	50	60	165	26
13	6-6	5:00	Raw water	1,500	+	+	60	60	.....	28
16	6-6	7:30	Raw water	650	0	.....	.....	.....	.....	25
			Average	1,000	.....	.....	53	60	172	25
		A. M.								
2	6-6	8:35	Effluent filter No. 1	33	.....	.....	0	0	.....	22
3	6-6	8:40	Effluent filter No. 2	75	.....	.....	0	0	.....	22
5	6-6	10:30	Effluent filter No. 1	38	.....	.....	0	.....	.....	.....
6	6-6	10:35	Effluent filter No. 2	16	.....	.....	0	.....	.....	.....
		P. M.								
8	6-6	1:05	Effluent filter No. 1	48	0	.....	0	0	144	25
9	6-6	1:10	Effluent filter No. 2	40	0	.....	0	0	.....	25
11	6-6	3:35	Effluent filter No. 1	90	.....	.....	0	0	.....	26
12	6-6	3:34	Effluent filter No. 2	42	.....	.....	0	0	.....	26
14	6-6	5:05	Effluent filter No. 1	120	.....	.....	0	0	.....	28
15	6-6	5:10	Effluent fitler No. 2	.....	.....	.....	0	0	.....	28
17	6-6	8:30	Effluent filter No. 1	90	.....	.....	.....	.....	.....	26
18	6-6	8:35	Effluent filter No. 2	70	.....	.....	.....	.....	.....	26
			Average	59	.....	.....	0	0	144	26
		A. M.								
19	6-7	8:00	Raw water	275	.....	.....	50	60	160	.....
22	6-7	9:30	Raw water	960	.....	.....	.....	.....	.....	22
25	6-7	11:30	Raw water	475	.....	.....	.....	.....	173	30
		P. M.								
28	6-7	3:15	Raw water	190	0	0	50	55	.....	30
			Average	475	0	0	59	58	167	25
	1906	A. M.								
20	6 7	8:30	Effluent filter No. 1	110	0	.....	0	0	.....	26
21	6-7	8:35	Effluent filter No. 2	.....	0	0	0	0	.....	26
23	6-7	10:00	Effluent filter No. 1	180	.....	.....	0	0	160	.....
24	6-7	10:05	Effluent filter No. 2	75	.....	.....	0	0	160	.....
		M.								
26	6-7	12:00	Effluent filter No. 1	75	.....	.....	.....	.....	.....	29
27	6-7	12:00	Effluent filter No. 2	65	.....	.....	.....	.....	.....	29
		P. M.								
29	6-7	3:20	Effluent filter No. 1	31	0	0	0	0	115	29
30	6-7	3:20	Effluent filter No. 2	20	0	+	0	0	125	29
31	6-7	5:15	Effluent filter No. 1	60	0	+	.. ..	.....	.....	.....
32	6-7	5:20	Effluent filter No. 2	45	0	0	.....	.....	.....	.....
			Average	73	.....	.....	0	0	140	28
		P. M.								
527	9 19	2:30	Raw water	2,500	0	+	25	45	160	.....
532	9-19	5:00	Raw water	1,200	0	0	.....	.....	158	.....
533	9-19	9:00	Raw water	1,100	0	+	.....	.....	160	.....
529	9-19	3:15	Set. water top No. 1	500	.....	.....	.....	.....	.....	.....
528	9-19	2:45	Combined effluents	1,800	0	+	15	<5	142	.....
531	9-19	5:30	Combined effluents	500	0	0	15	<5	158	.....
534	9-19	9:00	Combined effluents	70	0	0	15	<5	142	.....
526	9-19	1:45	Clear well	700	0	0	15	<5	172	.....
530	9-19	5:30	Clear well	.....	.....	.....	25	<5	156	.....
		A. M.								
535	9-20	6:50	Raw water	650	0	+	25	65	154	.....
538	9-20	8:15	Raw water (river)	.....	.....	.....	25	65	154	.....
542	9-20	11:00	Raw water	950	.....	.....	.....	.....	156	.....

[1]Color on unfiltered samples.

TABLE NO. 43 — Continued.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	Temp.
	1906	P. M.								
546	9-20	3:00	Raw water	1,100	0	0	.....	.....	156	.....
550	9-20	9:45	Raw water	2,000	0	0	.....	.....	.....	.....
		A. M.								
552	9-21	7:30	Raw water (river)	1,400	.....	.....	.....	70	156	.....
537	9:20	7:30	Set. water top No. 1	1,200	.....	.....	.....	.....	.....	.....
540	9:20	8:30	Effluent No. 1	55	.....	.....	.....	.....	.....	.....
541	9:20	8:30	Effluent No. 2	75	.....	.....	.....	.....	.....	.....
539	9:20	8:30	Combined effluent	.....	.....	.....	15	<5	144	.....
544	9:20	11:15	Combined effluent	.....	.....	.....	15	<5	150	.....
		P. M.								
547	9:20	3:00	Combined effluent	50	0	0	15	<5	130	.....
549	9:20	9:45	Combined effluent*	1,700	0	0	15	<5	152	.....
		A. M.								
536	9:20	7:20	Clear well	700	0	+	20	<5	152	.....
543	9-20	11:00	Clear well	70	.....	.....	20	<5	160	.....
551	9-21	7:15	Clear well	75	.....	.....	15	<5	154	.....
		P. M.								
548	9-20	5:00	Leakage in clear well	1,200	0	0	0	<5	282	.....
545	9-20	2:30	Tap at Hotel Gottfried	90	0	0	15	<5	170	.....
	1907	P. M.								
912	1-9	1:30	Raw water	31,000	0	+	65	380	57	.....
915	1-9	1:45	Set. water top No. 2	8,900	0	+	.....	.....	17	.....
917	1-9	3:45	Set. water top No. 3	.....	.....	.....	5	.....	18	.....
913	1-9	1:30	Combined effluents	5,300	0	0	30	50	40	.....
916	1-9	3:30	Combined effluents	300	Frozen		5	<5	17	.....
914	1-9	1:30	Clear well	3,700	.....	.....	15	25	95	.....
		A. M.								
920	1-10	9:00	Raw water	12,800	0	+	45	150	80	8.0
		P. M.								
925	1-10	1:3	Raw water	6,300	+	+	25	110	87	.....
		A. M.								
921	1-10	9:30	Set. water top No. 2	5,200	.....	.....	.....	22	.....	.....
922	1-10	9:30	Combined effluent	1,100	0	+	5	<5	31	.....
923	1-10	11:00	Combined effluent	1,060	0	0	5	<5	42	.....
		P. M.								
926	1-10	1:30	Combined effluent	2,600	0	+	15	20±	62	.....
927	1-10	3:00	Combined effluent	5,700	0	0	10	5±	56	.....
		A. M.								
919	1-10	8:00	Clear well	3,400	0	+	10	20	100	.....
		P. M.								
928	1-10	3:30	Clear well	1,480	0	+	.....	16	84	.....
		A. M.								
918	1-10	7:00	Tap at Hotel Gottfried	2,700	0	0	8	25	112	.....
		P. M.								
924	1-10	1:00	Tap at Hotel Gottfried	2,700	0	+	.....	20±	103	.....
		P. M.								
1454	7-1	1:00	River water	3,100	+	+	30	50	183	.....
1455	7-1	1:30	Set. water top No. 2	2,500	+	+	.....	60	162	.....
1459	7-1	4:30	Set. water top No. 2	2,100	+	+	.....	50	164	.....

* No alum applied.

Incrustants, Sample No. 552, 128; Sample No. 548, 306; Samp. No. 545, 202. Total hardness, Sample No. 552, 284; Sample No. 548, 588; Sample No. 545, 372.

Incrustants, Sample No. 925, 122; Samp. No. 928, 178; Sample No. 924, 150.

TABLE NO. 43 — Concluded.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	
	1907									
1456	7-1	1:45	Effluent filter No. 1.....	450	0	0	15	<5	161	.....
1457	7-1	1:45	Effluent filter No. 1.....	325	0	0	15	<5	161	.....
1460	7-1	5:00	Effluent filter No. 1.....	220	0	0	12	<5	160	.....
1461	7-1	5:00	Effluent filter No. 2.....	250	0	0	12	<5	160	.....
1453	7-1	1:00	Clear well	110	0	0	15	<5	158	.....
1458	7-1	3:30	Clear well	200	0	0	15	<5	158	.....
		A. M.								
1464	7-2	8:45	River water	5,200	+	+	30	55	183	.....
1465	7-2	9:30	Set. water top No. 2.....	3,600	+	+	.....	65	162	.....
1466	7-2	9:45	Effluent filter No. 1.....	210	+	+	15	<5	157	.....
1467	7-2	9:45	Effluent filter No. 2.....	250	0	0	15	<5	157	.....
1463	7-2	8:30	Clear well	250	0	+	15	<5	164	.....
1462	7-2	7:00	Tap at Hotel Gottfried.....	90	0	0	18	<5	164	.....

Incrustants, Samp. No. 1464, 82; Samp. No. 1463, 120; Samp. No. 1462, 142.

VERMILLION.

The village of Vermillion is on Lake Erie, in Erie County, at the mouth of the Vermillion River. It has no manufacturies, and as the only industry, that of fishing, is limited to an open season of the year, the town is essentially residential. Its population was estimated in 1906 to be 1,250. As Vermillion is a favorite summer resort, there is a considerable influx of vacationists from June to September, and during this time its population is nearly doubled.

HISTORICAL.

When the installation of the waterworks was considered in 1903, two sources of supply were investigated, the one from the Vermillion River, and the other from Lake Erie. The water in the river is harder than that in the lake, and its physical characteristics are subject to more frequent and greater changes. Moreover, it receives a greater part of the sewage from Vermillion, and all the surface drainage from the watershed above the town. It was recommended by the State Board of Health that much more satisfactory results would be obtained if the supply were taken from Lake Erie than from the Vermillion River.

The intake was placed immediately to the west of the west break-water at the mouth of the Vermillion River. The prevailing current in Lake Erie is toward the east, during which times the supply is subject to pollution from a small stream, which discharges into the lake just west of the intake. As the general slope of the town is toward the west, during times of severe rains there is a considerable flow of surface water into this creek. When the wind is from an easterly direction, the currents in the lake are reversed, and at such times

the Vermillion River water is carried to the west of the breakwater, and over the location of the intake.

It is well known that the Lake Erie water is generally soft and fairly clear, and it was recognized that a much more satisfactory supply could be obtained for Vermillion from the lake than from the Vermillion River. When the waterworks were installed in 1904, the supply was taken from Lake Erie, and as it was recognized that there was at times a considerable local pollution of the lake water, and that it contained considerable suspended matter, frequently for periods of two or three months, it was necessary to include a filtration plant.

DESCRIPTION OF WATER WORKS.

Briefly stated, the Vermillion waterworks as constructed in 1904, comprise the following features: (See Plate XVIII.)

About 1,500 feet to the west of and nearly opposite the end of the west breakwater at the mouth of the Vermillion River is located an intake crib from which a cast iron pipe extends to a receiving well on the shore of the lake. Into this well extends the suction of the low service pump provided to lift the water to the coagulating tank. The latter, together with the coagulating tanks and the filter, are placed in a separate room of the pump house; beneath the filter room is built a clear well for the storage of filtered water. A high service pump is provided to force the water to a stand-pipe from which it flows by gravity into the distributing system. The pump house is a substantial brick building located in the north central part of the village near the Vermillion River.

Intake and Pump.

The intake is protected by a wooden crib with stone block filling and is carried out 1200 feet from the lake shore, where the depth of water is 11 feet. A 10-inch cast iron pipe, laid directly on the bottom of the lake extends from the crib to a receiving well on the shore. No riser is provided at the entrance to this pipe and the supply is taken from the bottom of the lake. The receiving well is 30 feet in diameter, with a total depth of 20 feet, but an available depth of but 16 feet, which gives a net capacity of 80,000 gallons. It was intended that the heavier matter in suspension in the lake water would be deposited in this basin, but from the fact that the outlet is at the bottom and immediately opposite the inlet, this basin has very little if any efficiency in removing the suspended matter. From the well a 10-inch cast iron pipe, 500 feet in length, is provided as a suction for the raw water pump. The latter is single acting of the Weinman type, with a nominal capacity of 200 gallons per minute at 50 revolutions. The total lift onto the coagulating tank is 17 feet, 8 of which is by suction.

Coagulating Tank.

The coagulating tank consists of a wooden tub, 8 feet in diameter by 8 feet high, of 3,000 gallons capacity. At 208 gallons per minute, the usual rate of pumping, the length of the coagulating period is 14 minutes. There are no baffles in the tank and a circular motion is imparted to the coagulated water by an elbow at the inlet. All of the fittings are of 5-inch wrought iron pipe; the inlet is in the side near the bottom, while the outlet is 2'-4" below the top. This outlet is too small, as there is too high a velocity of water in the pipe, causing a breaking up of the coagulated masses in the applied water.

Coagulants and Means For Application.

Before entering the coagulating tank the water is treated with the coagulants which consist of copperas and lime. The copperas is obtained in the ordinary crystallized form from the American Steel & Wire Company at $6.60 per ton delivered; while the lime, manufactured on Kelly's Island, is supplied by a local dealer at $10.00 per ton. The latter is slaked in a pail, while the coagulant is added each night directly to the solution tank. There are two tanks for the lime solution, one of steel, 4 feet in diameter by 4 feet high of 375 gallons capacity, and one of wood, 3.5 feet in diameter by 7.0 feet high, with a capacity of 500 gallons. The copperas solution is prepared and stored in a steel tank 4 feet in diameter by 4 feet high of 375 gallons capacity.

The solutions are forced into the raw water pipe supplying the coagulating basin by two small, direct acting pumps immediately connected to the larger raw water pump and the point of application of each solution is at the raw water pump. The rate of application of both solutions is thus made to vary directly with the rate at which the raw water is pumped.

Filter.

One filter is provided which consists of a wooden tub 14 feet in diameter, with an area of 154 square feet or 0.00353 acre. Its strainer system is formed by a manifold of extra strong 1¼-inch wrought iron pipes into which are screwed, on 6-inch centers, 612 "Ideal" brass strainers. The filtering material was obtained from Norcross and Edmunds of Birmingham, N. J., and as originally installed consisted of 32" of sand with an effective size of 0.40 m. m. and a uniformity coefficient of 1.5 supported on 6" of gravel of an effective size of 2.0 m. m. and a uniformity coefficient of 1.5 which in turn rested on 4" of gravel of an effective size of 4.4 m. m. and a uniformity coefficient of 1.3. It has been found, however, that the sand and gravel composing the two upper layers have been intermixed, and that the resulting mixture has an effective size of 0.57 m. m. and a uniformity coefficient of 1.8.

The filter is washed by filtered water applied directly from the mains. Mechanical rakes extending 14 inches into the sand are used to assist in the washing, although it is found that the 1 H. P. water motor provided has not sufficient power to force the rakes through the sand, so that it is necessary to reverse the agitator and drag the rakes over the surface.

Storage of Filtered Water.

The effluent from the filter is stored beneath the filter room in the clear well, which is 9′ wide X 20.5′ long X 8.0′ deep, and has a capacity of 11,000 gallons. The length of the storage period at the usual rate of operating the filter, 208 gallons per minute, is 53 minutes. When the clear well is full, there is a total available head on the filter of 10 feet.

From the clear well the filtered water is forced to the stand-pipe through an 8-inch cast iron force main, 650 feet long, by a McGowan compound duplex steam pump. This has a 12-inch stroke, with an 8½-inch water cylinder. The stand-pipe is a steel tank of 100,000 gallons capacity, located in the north central part of Vermillion, at such a height as to give a pressure of 45 pounds per square inch in the mains.

EXAMINATIONS.

During the special investigation by the State Board of Health, the purification plant at Vermillion has been visited six times; on May 26th, August (15-16), October (24-25), 1906, February 7th, June (11-13), October 15th, 1907. On May 26th, 1906, and October 15th, 1907, the plant was inspected, but on the other four visits regular examinations were made. Particular attention was given during the last two examinations to the methods of applying the coagulants.

OPERATION.

When the plant is in operation, water flows by gravity into the receiving well, from which it is pumped into the coagulating tank, receiving the coagulants on the way. From the coagulating tank it flows by gravity through the filter into the clear well, and is forced by the high service pump into the stand-pipe.

One engineer is employed to operate the plant. There is a considerable variation in the water consumption at Vermillion, and the engineer's hours of service vary at different seasons of the year. During the summer months it is sometimes necessary to operate the plant for 14 hours, while in the winter, it is frequently possible to filter a sufficient quantity of water in 5 or 6 hours. The capacity of the plant is limited by that of the raw water pump, as it would be possible to operate the other features of the plant at a rate sufficient to considerably reduce the maximum period of operation required.

During the special investigation by the State Board of Health, careful records of the daily operation of the Vermillion plant have been kept by the engineer, and their monthly averages are shown in Table No. 44. The average daily consumption has increased from 50,000 gallons per day in 1905 to 79,400 gallons per day in 1907, and it is apparent that, with this very rapid increase, the maximum capacity of the plant will soon be reached. It will then be necessary either to install additional units, particularly a raw water pump, coagulating basin and a filter, or to operate the plant for 24 hours, particularly during the warmer season.

Application of Coagulant.

The lime water is prepared by first slaking five pounds of lime in a pail, and then adding the resulting milk of lime to the storage tank, where it is diluted to a strong lime water, and is stored until used.

As it is seldom necessary to empty the copperas solution tank during the day's run, it is the custom to add at the end of each run a sufficient quantity to replace that which has been applied during the day. The charge is placed in a perforated box in the top of the tank, which is then filled with water, and in a few hours the copperas is entirely in solution.

The quantities of coagulants applied are determined by the speed of the solution pumps, by the degree of opening of the regulating valves, and by the strengths of the solutions. These three factors permit a flexible application of the coagulant, and have proven very satisfactory. It is generally the custom to keep the solution of constant strength, and to vary the quantity of coagulant applied by changing the degree of opening of the regulating valves in the solution piping. It will be seen from the daily records that there has been but little yearly variation in the amount of coagulants applied daily, which has varied from 1.3 grains per gallon to 1.4 grains per gallon, while the amount of lime used has varied from 0.5 to 0.6 grain per gallon. The maximum amount of coagulant that it has been necessary to apply at Vermillion, as shown by the

daily records, is 4.4 grains of copperas per gallon, which required 1.9 grains of lime per gallon. This was on May 7th, 1907, when the lake intake was being cleaned and the supply was taken temporarily from the river.

Coagulating Tank.

The operation of the coagulating tank requires little comment, but it is of interest to note that, in the absence of controlling devices, it is necessary to operate the filter and raw water pump at the same rate in order to prevent an overflow of the coagulating tank, or the uncovering of the sand in the filter.

Filter.

Rate of Filtration. In the absence of automatic controllers the rate of filtration is governed by the degree of opening of the valve on the effluent from the filter. This valve is generally left wide open, causing the filter to run at its maximum possible rate. During the examinations numerous measurements of the rate of filtration were made, from which the average rate of filtration has been found to be about 85,000,000 gallons per acre per day.

At times, although the effluent valve was wide open, there was a decided decrease in the rate of operation of the filter, due to the fact that its effluent pipe was not running full. It is necessary to keep sufficient water in the clear well in order that the outlet from the filter be constantly submerged, as when this is not done the effluent pipe does not run full and there is a decrease in the rate of filtration from 85 to 60, or even 50, million gallons per acre per day.

Washing. As the wash water is obtained directly from a connection to the force main, its rate of application varies with the degree of opening of the controlling valve, and although it has been found to vary somewhat, the average rate is very nearly 0.60 foot per minute, corresponding to 690 gallons per minute. The water is applied for about 10 minutes, and about 6 vertical feet are used per wash.

The average quantity of wash water as shown on the daily records from September, 1906, to September, 1907, is 13 per cent., a quantity which is unusually large, and is due in part to the insufficient capacity of the coagulating tank and in part to the absence of efficient agitation. The maximum quantity of wash water used during one month was in January, 1907, when 20 per cent. of the total amount of water pumped was used to wash the filter.

Although the quantity of wash water used is large, it has always been found that the filtering material was in good condition and that there were no deposits of incrustants of lime in the sand.*

It is probable that the large quantity of wash water is due in part to the use of copperas as a coagulent, as the precipitated iron hydrate is heavy, sticky and difficult to remove with the ordinary rates of application of wash water.

CHARACTER OF RAW WATER.

During the various examinations, samples of untreated water were taken, both from the lake at the surface near the intake, and also from a tap near the raw water pump. In this manner it was possible to determine the changes in the character of the raw water effected by the settling basin on the shore of the lake. As the evidence shows considerable changes in the character of the water, due principally to weather conditions, they are discussed below under the head of each examination.

Note. In March, 1908, the brass strainers in the filter became so clogged with incrustants of lime that it was necessary to remove them and to treat them with muriatic acid.

Examination of August 15, 1906.

The results obtained at the examination of August 15th, 1906, are of particular interest in that they show a considerable variation in the character of the raw water, and the changes effected when the river water is carried over the intake. On August 15th the wind was from a westerly direction, and the river water was carried toward the east, so that the water at the intake consisted entirely of normal lake water. During the night, however, an easterly wind sprung up, causing a reversal of the current in the lake, and the water at the intake on the 16th was then largely intermixed with that from the river. It is of interest to note the rapid increase in bacterial count and the slight decrease in alkalinity of the raw water.

Examination of October 23, 1907.

On October 23rd, 1907, there was a strong breeze from the south, that is off the shore, and that such a wind has little effect on the character of the lake water is shown by its low turbidity. During the night, however, the wind changed, and a very strong northwest wind came up, which made the lake quite rough and soon caused an increase in turbidity from 80 to 170 parts per million. Contrary to what might be expected, there was no corresponding increase in the bacterial content of the raw water, but a decided decrease. At such times the increase in suspended matter in the lake is caused by the wave action on the bottom, and does not consist of surface washings.

The effect of such a wind in causing currents was very well demonstrated during this examination, as the level of the water in the lake fell about two feet during the morning of October 16th. This indicated a very strong current toward the east.

That there was some contamination caused by the river water on October 23rd, is indicated by the presence of coli in the raw water, although in small numbers.

Examination of February 7th, 1907.

During the examination of February 7th, 1907, the lake was covered with ice, and the raw water had a low turbidity. Although no coli were present, the number of bacteria contained was large. The fact that the alkalinities were below the normal would indicate that the lake water was partially intermixed with water from the river.

Examination of June 11th, 1907.

Fair weather prevailed during the examination of June 11th, and 12th, 1907, and there was a moderate wind blowing from the northwest.

During this examination quantitative determinations were made for coli, and the evidence obtained indicates that there were at least two in each c. c. of raw water. This number is unusually high, as coli were found on but one previous examination, and then only in 100 c. c. It is of interest to note at this time the presence of coli in 100 c. c. of filtered water, even when the total bacterial content is very low. This pollution of the raw water was undoubtedly due to drainage from Vermillion.

Summary.

The evidence obtained during the special investigation indicates that, under normal conditions, the lake water at the intake of the Vermillion waterworks is not polluted, is generally soft, contains but very little dissolved color, and

requires only the removal of its suspended matter to give a resulting supply of very satisfactory quality for domestic use. That it is occasionally polluted, however, is due to the location of the source of supply near the mouth of the Vermillion River, which is occasionally carried over the intake by the lake currents. At such times, not only is it necessary to improve the physical character of the water, but also a high bacterial removal is required in order to produce a wholesome supply.

It is also apparent that the occasional high turbidities of the lake water which result from strong westerly winds are accompanied by no pollution of the lake water, and on the contrary the engineer at the waterworks has found that under these conditions it is much more easy to successfully operate the plant than during such times as the lake water contains but little suspended matter.

Influence of Receiving Basin.

It has been noted during the examinations that there is a decrease in the turbidity of the raw water at the pump, as its run continues. This is due to the fact that, after the plant is shut down at night, the water stored in the receiving basin has about 12 hours sedimentation. When the pump is started in the morning, as its suction is at the bottom of the well, the water which it first receives contains part of the suspended matter deposited during the night.

During these examinations it has been recommended by the State Board of Health that the outlet to this basin should be changed from the bottom to the top. This change should much improve its efficiency of sedimentation.

CHARACTER OF RIVER WATER.

On account of stoppage by leaves and other sediment, it was found necessary to clean the lake intake in the spring of 1907, which cleaning was accomplished from May (6-17). During this time the water supply was obtained by an emergency intake into the Vermillion River, which unfortunately was very turbid. The river water contained large amounts, not only of suspended matter, but also of color, for the removal of which it was found necessary to use a very large quantity of coagulant. The maximum turbidity of the river water recorded was 800 parts per million, and at this time 4.4 grains of copperas per gallon and 1.9 grains of lime per gallon were applied. Even with these large amounts of coagulant, the treated water contained considerable dissolved color. The average turbidity during this period was 580 parts per million, and 3.6 grains of copperas per gallon and 1.5 grains of lime per gallon were the average quantities of coagulants required.

These results are of particular interest, as it was first intended to use the river as a source for the Vermillion supply, and it was only on account of the recommendations of the State Board of Health that lake water was finally used.

EFFICIENCIES.

Guarantee.

The contract for the filter plant contained a guarantee that the efficiency "shall be such as will meet the approval of the State Board of Health, and that with all possible conditions of raw water will deliver filtered water free from sediment, color or odor." The efficiency required by the Board is as follows: "The resulting water shall be clear, odorless, free from turbidity and from

all matters in suspension as seen by the naked eye; and the removal of bacteria shall not be less than 98 per cent. when the water contains 3,000 or more per c. c. and when the applied water contains less than 3,000 bacteria per c. c. the efficiency shall be such that not more than 100 bacteria shall be found in the filtered water."

Expert Supervision.

In order to determine the quality of the Vermillion water supply a bacteriologist was employed by the Board of Trustees of Public Affairs to make two bacterial tests per week. As the plant has given very satisfactory results, these examinations have been discontinued since May, 1907.

The cost to the Board for these examinations was $15.00 per month and expenses.

Receiving Well.

The evidence obtained during the special investigation shows that there has been practically no removal of suspended matter or bacteria accomplished by the receiving well. This is due to fallacies in the original design, as it will be seen in drawings on Plate XVIII, that the inlet to the basin is at the top and the outlet at the bottom. In order to assure the best operation of this well, the relative position of these pipes should be reversed, that is, the inlet should be at the bottom and the outlet at the top of the well. These changes could be readily accomplished by providing an elbow and drop on the inlet and a riser at the outlet, in which case, however, a separate drain should be provided to flush out the well.

The attention of the Board of Public Affairs has been called to these necessary changes, which, however, have not been made.

Methods of Applying Coagulant.

On the examinations of February 7th and June 11th, 1907, samples of both coagulant solutions were obtained from the piping near the solution pumps. All of these samples were titrated, and their available strength determined at the plant. The purpose of these examinations was to determine both the actual quantities of coagulants applied, and also the ease with which they were handled.

The results of the examinations of February 7th indicate that the lime solution was practically of constant strength during the run-off of each tank. The solution varied in strength from 59 to 64 grains per gallon, while the average amount of CaO contained was 62 grains per gallon. As the theoretical strength of the solution, considering the lime 100 per cent. CaO, was 96 grains per gallon, it is evident that 65 per cent. of the lime was available.

The iron solution weakened toward the end of the run-off of the tank, and its strength varied from 501 to 407 grains per gallon. The average strength was 469 grains per gallon, and as the tank contained 25 pounds of copperas and the theoretical strength was 518 grains per gallon, it will appear that 91 per cent. of the copperas was available. The copperas was applied during this examination at the rate of 1.0 grain per gallon, and the lime at 0.4 grain per gallon. These figures are based on the actual amounts applied as determined by the titration of the samples.

The results of the chemical analyses obtained during this examination are of particular interest, as unusually large quantities of lime compared with copperas were used, resulting in the formation of considerable normal carbonates in the filtered water. The average quantity of normal carbonates in the filtered water was 26 parts per million, while in one sample from the Lakeside Inn 92 parts per million were found. The evidence indicates that during cold weather

when more than that quantity of lime sufficient to neutralize the copperas is added, there does not result a softening of the treated water until there is a considerable quantity of normal carbonate present in the filtered water. That the temperature and also the length of time allowed for coagulation have considerable influence on the resulting reaction is indicated by the different results obtained under similar treatment at Lorain in June, 1907, which are discussed on page 183. The effect of the use of too small a quantity of lime is shown on the sample from the force main at 10:15 A. M., and it will be noted that the water contained three parts per million of acidity to phenolphthalein, a considerable quantity of dissolved color, and less total alkalinity than the untreated water. Under these conditions there resulted also a poor bacterial removal by the basin and filter.

On the examination of June 11th, similar tests of the methods of applying the coagulant were carried out, and as before the lime water was found to be practically of constant strength throughout the running-off of a tank. The available CaO for the two days run was 67 per cent. Although the copperas had a theoretical strength of 524 grains per gallon, by the analyses it was shown to contain 544 grains per gallon. This increase in available copperas is from the fact that the stronger solution settles to the bottom and as the tank is not emptied during a day's run, and the amount used from it is replenished at night, the resulting solution is slightly stronger than if the tank had been emptied and refilled after each run. Contrary to the results of the first examination there was but slight variation in the strength of the copperas solution.

On June 11th, 0.95 grain of copperas per gallon and 0.48 grain of lime per gallon were applied, while on June 12th the amounts used were 1.5 and 0.69 grains per gallon respectively.

That the coagulant solutions have been found of such constant strength is of particular interest from the fact that no mechanical or other agitation is provided in any of the storage tanks. It has been found at Vermillion that the best results are obtained from the plant when the solutions are applied in the proportion of about one grain of copperas per gallon to 0.4 grain of lime per gallon in bulk. There results a small quantity of normal carbonates in the filtered water. During the operation of the Vermillion plant the engineer frequently tests the filtered water to see that it contains a slight, and only a slight pink color when tested with phenolphthalein.

That no softening of the treated water is accomplished by the use of greater amounts of lime during the winter months is due in part to the short period allowed for the coagulation before the water is applied to the filter, and in part to the low temperature of the water treated.

Coagulating Basin.

The evidence obtained during the special investigation tends to show that there is a great variation in the work accomplished by the coagulating basin. The bacterial removals have varied from 0 to 48 per cent. On June 12th, 1907, there was no removal of bacteria in the coagulating tank, and the water applied to the filter had a greater turbidity than the raw water. Under ordinary conditions the bacterial removal by the basin is not greater than 33 per cent. The best results have been obtained with comparatively high turbidities of the treated water.

Not only is the tank of too small capacity, but there is a decided rotary motion of the water in the tank, tending to eliminate any deposition of suspended matter; also, the small size of the outlet produces too great a velocity of the water on the filter with a consequent breaking up of the coagulated masses.

The poor preparation of the water applied to the filter results in the use of unusually large quantities of wash water and, at times of high turbidity, in the necessity for excessive quantities of coagulant. Much greater economy in the operation of the plant would result were the capacity of the coagulating tank increased until the period allowed is at least five hours.

Filter.

On each of the several examinations, with the exception of that of February 7th, 1907, there has been an average of less than 100 bacteria per c. c. in the filtered water. On February 7th, the efficiency of the coagulating tank was but 29 per cent. and there was more suspended matter in the water applied to the filter than in the raw water. It is apparent that there was not a sufficient amount of coagulant used, and at this examination the engineer was advised that better results would obtain with the use of larger quantities of coagulant. That the water was potable is indicated by the absence of coli.

On the examination of June (11-12), 1907, coli were found in 100 c. c. samples of filtered water. This fact is consistent when it is considered that at least two were present in each c. c. of raw water, and that, although the total number of bacteria in the effluent from the filter was low, there still remained a few coli.

REVIEW OF EFFICIENCY OF PLANT DURING SPECIAL INVESTIGATION.

In general it may be said that although considerable difficulty is occasionally encountered at the Vermillion plant, the evidence would indicate that the supply as pumped to the city is always potable and very satisfactory for domestic use. The wholesomeness of the supply is proven by the absence of typhoid among the consumers.

A considerable increase in economy of operation might be accomplished by making the suggested changes at the receiving well, and also by providing a longer period for the coagulation of the applied water. The latter would result in the use of less wash water and coagulants, while the changes at the settling well would increase its efficiency and also assist in obtaining better results when the raw water is very turbid.

The results at Vermillion are of particular interest at they are obtained without expert supervision, and it has generally been considered impossible to satisfactorily operate a small plant without at least occasional expert control.

COST OF INSTALLATION.

The total net cost of the Vermillion waterworks to January 1st, 1907, was $40,249.88. Besides the distributing system and minor repairs this includes the cost of installation of the various features shown in the following table:

Intake and crib	$5,901 65	
Receiving well	2,013 14	
Suction	459 26	
Filter*	1,527 58	
Building	2,196 47	
Stand-Pipe	4,805 07	
Total		$16,903 17

* Includes raw water pump. filter and coagulant apparatus.

COST OF OPERATION.

The cost of operating the Vermillion plant is shown below, and comprises cost of labor, coagulants, and coal, based on the following figures:

Engineer's salary	$900 00 per yr.
Copperas, per ton delivered	6 60
Lime, per ton delivered	10 00
Coal, per ton delivered	2 25

The total water pumped during 1907, based on the daily records, was 28,987,060 gallons.

Total pounds of copperas used — 6,205 at $.0033	$20 45
Total pounds of lime used — 2,555 at $.0050	12 78
Total tons of coal used — 147 at $2.25	331 00
	$364 23
Engineer's Salary	900 00
Total cost of operation	$1,264 23
Average cost per million gallons	$43 70

TABLE NO. 44.

Vermillion — Record of Operation.

Month.	Average Daily Consumption.	Coagulants. Lbs. Used. Cop.	Coagulants. Lbs. Used. Lime.	Coagulants. Gr. P. Gal. Cop.	Coagulants. Gr. P. Gal. Lime.	Wash Water. * Gallons.	Wash Water. * Per cent.	Turbidity of Raw Water.	Pounds of Coal Used.
1905.									
August	60,000	12	6	1.4	0.7	.....	.....	.....	924
September	46,000	9	4	1.3	0.6	.....	.....	.....	795
October	43,000	8	3	1.3	0.6	.....	.....	.....	744
November	46,000	9	3	1.3	0.4	.....	.....	.....	785
December	53,000	11	4	1.4	0.5	.....	.....	.....	795
Average	49,600	10	4	1.3	0.6	.....	.....	.....	809
1906.									
January	58,000	10	3	1.2	0.4	.....	.....	.....	755
February	100,000	16	7	1.1	0.5	.....	.....	.....	1,061
March	55,000	10	4	1.2	0.5	.....	.....	.....	860
April	56,000	11	4	1.3	0.5	.....	.....	.....	835
May	56,000	11	4	1.3	0.5	.....	.....	.....	777
June	70,000	13	5	1.3	0.5	.....	.....	.....	843
July	81,000	15	6	1.3	0.5	.....	.....	.....	910
August	59,000	11	4	1.3	0.4	.....	.....	.....	810
September	68,000	13	5	1.3	0.5	7,590	11.1	.....	762
October	53,000	10	4	1.3	0.5	6,900	13.0	.....	735
November	64,000	16	7	1.7	0.7	9,660	15.0	.....	768
December	65,000	10	4	1.0	0.4	8,970	13.8	.....	829
Average	65,417	12	5	1.3	0.5	8,280	13.2	.....	829

TABLE NO 44 — Concluded.

Month.	Average Daily Consumption.	Coagulants.				Wash Water.*		Turbidity of Raw Water.	Pounds of Coal Used.
		Lbs. Used.		Gr. P. Gal.					
		Cop.	Lime.	Cop.	Lime.	Gallons.	Per cent.		
1907.									
January	76,000	20	8	1.8	0.7	15,180	19.9	78	794
February	84,000	17	7	1.4	0.6	8,970	10.6	50	867
March	76,000	18	7	1.6	0.7	12,420	16.3	122	834
April	66,000	19	9	2.0	0.9	.....	.....	.....	817
May	71,000	25	10	2.4	0.9	9,660	13.6	288	813
June	75,000	15	6	1.4	0.6	9,660	10.2	67	797
July	85,000	13	5	1.0	0.4	9,660	11.3	40—	542
August	102,000	14	7	1.0	0.5	9,660	9.4	40—	968
September	80,000	9	4	0.8	0.4	9,660	12.0	40—	790
Average	79,444	17	7	1.4	0.6	10,609	12.9	91	802

* 690 gallons of wash water used per minute.

TABLE NO. 45.

Vermillion — Results of Analyses During Examinations.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	Phen Alk.
	1906	A. M.								
380	8-15	11:00	Lake, surface near intake...	1,800	.....	.....	.....	35	90	.....
373	8-15	8:00	Raw water[1]	280	.....	.....	4	60	91	0
376	8-15	9:30	Raw water	360	.....	.....	4	60	90	.....
378	8-15	10:40	Raw water	325	.....	.....	.....	45	91	.....
			Average	322	.....	.....	4	55	91	.....
374	8-15	8:00	Filtered water	56	.....	.....	0	<5	103	2
377	8-15	9:30	Filtered water	20	.....	.....	0	<5	98	1.5
379	8-15	10:40	Filtered water	15	.....	.....	0	<5	92	6
			Average	31	.....	.....	0	<5	96	3
375	7-15	8:38	Rewash	50	.....	.....	.....	.....	.....	.....
381	8-16	7:45	Lake, surface near intake..	1,700	0	0	4	55	88	1.0
382	8-16	8:30	Raw water	680	0	0	4	60	86	0.5
384	8-16	10:00	Raw water	1,100	0	0	4	50	86	0.5
			Average	890	0	0	4	55	86	0.5
383	8-16	8:30	Filtered water	18	0	0	2	<5	92	2.5
385	8-16	10:00	Filtered water	7	0	0	2	<5	88	0.5
386	8-16	11:30	Filtered water	17	0	0	2	<5	82	0
			Average	14	0	0	2	<5	87	1.0

Iron, samp. 374, 0.3; samp. 379, 0.2; samp. No. 383, 0.3; samp. No. 385, 0.6.

[1] Temp., 23° C.

Aug. 15th, 1906; used 1.50 grains of copperas per gallon, and 0.64 grain of lime per gallon.

TABLE NO. 45 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	Phen Alk.
	1906	A. M.								
757	10-24	11:00	Lake at intake.....	1,000	0	+	.....	70	97	1
758	10-24	8:15	Raw water	2,500	0	+	5	80	99	0.5
754	10-24	9:00	Settled water	1,800	.....	.....	.....	.....	99	1
752	10-24	7:30	Filter effluent	200	0	0	3	<5	102	2
755	10-24	9:30	Filter effluent	85	.....	.....	.....	<5	98	3
			Average	143	.....	.....	3	<5	100	2.5
751	10-24	7:00	Tap at Lakeside Inn.....	210	0	0	3	<5	98	1
756	10-24	10:15	Tap at McGowan's store...	55	.....	.....	2	<5	99	1
758	10-25	9:00	Raw water	325	0	0	.....	90	101	0.5
761	10-25	10:30	Raw water	900	0	0	5	170	99	0.5
			Average	600	0	0	5	130	100	0.5
760	10-25	9:30	Settled water	325	.....	.....	.....	101	0	.....
759	10-25	9:00	Effluent from filter.....	50	0	0	2	<5	103	2
763	10-25	11:30	Effluent from filter.....	33	0	0	.....	.....	.....	.....
			Average	42	0	0	2	<5	103	2
762	10-25	11:00	Tap at McGowan's store...	25	0	0	3	<5	101	1
	1907	A. M.								
1013	2-7	10:15	Raw water[1]	2,550	0	0	10	35	86	.....
		P. M.								
1020	2-7	2:00	Raw water	3,100	0	0	.....	35	86	.....
			Average	2,800	0	0	10	35	86	.....
		A. M.								
1014	2-7	10:15	Settled water	3,400	0	0	.....	.....	92	12
		P. M.								
1021	2-7	2:00	Settled water	650	0	0	.....	.....	96	24
			Average	2,000	0	0	.....	.....	94	18
		A. M.								
1015	2-7	10:15	Filter effluent	1,500	0	0	4	<5	88	.....
1017	2-7	11:45	Filter effluent	550	0	0	4	<5	91	16
		P. M.								
1019	2-7	1:15	Filter effluent	620	0	0	.....	<5	94	21
1022	2-7	2:45	Filter effluent	500	0	0	4	<5	91	14
1023	2-7	4:30	Filter effluent	650	0	0	.....	<5	.....	16
			Average	750	0	0	4	<5	91	17
1018	2-7	1:00	Tap at Lakeside Inn.....	425	0	0	4	<5	91	16
		A. M.								
1016	2-7	10:15	Tap at force main.....	1,160	0	0	10	<5	86	.....

Incrustants, sample No. 757, 10; samp. No. 758, 16; samp. No. 759, 25;
Iron, samp. No. 758, 1.5; samp. No. 762, 1.0.
Oct. 24-25, 1906, used 1.35 grains of copperas per gallon and 0.59 grain of lime per gallon.
CO_2, samp. No. 1013, 1.0; samp. No. 1020, 1.5; samp. No. 1015, 1.0; samp. No. 1016, 4.0.

[1] Lake covered with ice.
Feb. 7, 1907, used 1.07 grains of copperas per gallon and 0.60 grain of lime per gallon.

TABLE NO. 45 — Concluded.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in .5 c. c.	Colon in 1. c. c.	Colon in 2. c. c.	Colon in 100 c. c.	Parts Per Million. Col.	Turb.	Alk.	Phen. Alk.
	1907	A. M.										
1434	6-11	8:00	Raw water	670	+	+	+	....	8	90	80	0
1439	6-11	10:00	Raw water	1,000	+	+	0	....	8	75	80	0
		P. M.										
1444	6-11	3:00	River water (5 miles above intake)	200	0	0	0	+*	45	20±	98	....
1445	6-11	4:30	River water (end of breakwater)	760	0	+	+	....	45	40	88	—
		A. M.										
1435	6-11	8:30	Settled water	1,000	....	....	....	....	....	100	64	....
1438	6-11	9:00	Settled water	.....	....	....	....	....	....	100	68	....
1440	6-11	10:00	Settled water	.....	....	....	....	....	—	95	83	7
1436	6-11	8:00	Filter effluent	23	....	0	....	0	6	<5	83	2
1437	6-11	9:00	Filter effluent	55	....	0	....	+	8	<5	88	2
1441	6-11	10:00	Filter effluent	32	....	0	....	+	6	<5	88	2
		P. M.										
1438	6-11	4:30	Filter effluent	.....	....	....	....	....	5	<5	78	....
1443	6-11	1:30	Public Fountain	21	....	0	....	+	10	<5	83	2
		A. M.										
1442	6-11	11:00	Lake at intake	1,000	0	+	0	....	6	60	78	0
1447	6-12	9:00	Raw water	1,250	....	....	....	....	8	75	80	0
1452	6-12	11:30	Raw water	.....	....	....	....	....	8	50	83	0
1448	6-12	9:00	Settled water	1,100	....	....	....	....	....	75	91	12
1453	6-12	11:30	Settled water	Plates slid	....	....	....	....	....	.....	93	11
1446	6-12	8:30	Filtered water	.....	....	0	....	0	6	<5	76	3
1449	6-12	10:00	Filtered water	55	....	0	....	+	6	<5	73	8
1451	6-12	11:30	Filtered water	.....	....	....	....	....	6	<5	77	7
1450	6-12	10:30	Public Fountain	10	....	....	....	....	6	<5	77	3

CO_2, samp. No. 1444, 1.0; samp. No. 1445, 1.0; samp. No. 1435, 7.0; samp. No. 1438, 7.0.
June 11, 1907, used 0.95 grain of copperas per gallon and 0.48 grain of lime per gallon.
June 12, 1907, used 1.50 gr. copperas per gallon and 0.69 grain of lime per gallon.
* In 50 c. c.

WARREN.

The city of Warren, the county seat of Trumbull County, is in the northeastern part of Ohio on the Mahoning River, about sixteen miles above Youngstown, and forty-six miles below Alliance. Although it contains several manufacturing establishments, there is a noticeable absence of steel industries and the accompanying large percentage of foreign population found in most towns of the Mahoning River valley. The streets are clean, well paved, and on the whole Warren is one of the most attractive cities in the state. Its population was estimated to be 12,000 in 1906, with but slight increase for several years.

HISTORICAL.

The waterworks were installed by the Warren Water & Light Company in 1887, using the Mahoning River as a source, without purification. A study of

Warren. — Interior of Filter House.

this river was made during the special investigation by the State Board of Health in 1898, and the following information was taken from the report of these investigations. The area of the watershed above the Warren waterworks is estimated at 596 square miles, with a rural population in 1890 of about 43 per square mile as compared with an average of 50 for the entire state. Alliance, with an estimated population of 12,000, is the only city on the stream above Warren, and its sewage is discharged into the river after treatment by chemical precipitation. It has been found, however, during the recent special investigation by the State Board of Health that practically no purification of the sewage is effected. From Alliance the stream flows in a general northerly direction through rolling farm land. Between Alliance and Warren, a distance of about 46 miles, there are six mill dams originally used for furnishing power to flour mills, and it is probable that there is a considerable purification of the water due to sedimentation in the pools formed above these dams.

The nearest source of pollution to the Warren supply is at Leavittsburg, which is situated on the steep banks of the river, into which all of the surface drainage of the village is washed. There is also a constant danger of pollution by the sewage from the Trumbull County Infirmary. The infirmary is situated but three miles above the intake of the Warren waterworks, and the effluent from the coke filters, by which the sewage is purified, discharges into a small creek and is carried directly into the river. Chemically, the purification accomplished has been found very satisfactory, but it is probable that there is not a very high bacterial removal by the plant.

On account of the possible dangerous pollution of the Mahoning River, and from the fact that the water frequently contains objectionably large quantities of suspended matter and dissolved color, a purification plant was installed for the Warren supply in 1895.

DESCRIPTION OF PLANT.

The purification plant of the Warren Water & Light Company is located on the Mahoning River about one mile above the center of the town. It comprises the following general features: An intake above Camp and Randall's dam, a low service pump, a settling basin and coagulating system, six wooden mechanical filters, and a clear well. There are two high service pumping plants provided; the one is in the building adjacent to the filter house and is used for fire protection, forcing the water directly into the mains; while the other is across the river in the lighting plant and is used to lift the filtered water to the stand-pipe which supplies the ordinary consumption.

Intake and Raw Water Pump.

The dam was originally built for water power development and is of stone and concrete construction, 6½ feet high, 250 feet long and backs up the water about 3½ miles. The intake is just above the dam and consists of a 20-inch cast iron flanged pipe, laid on the bottom of the river. There is no provision for taking the water at any other level. One centrifugal pump of 3 million gallons capacity is provided for lifting the raw water to the coagulating basin. It has a total lift of approximately 5 feet.

Coagulating Basin.

The coagulating basin is included under the roof of the filter house and consists of a rectangular tank of stone masonry. It is 50 feet long X 22 feet

wide X 11 feet deep, and is divided by one vertical baffle through the center into two compartments of equal size, so that the water travels through the basin its entire length twice. The capacity of the basin is 78,000 gallons, which, at the average rate of pumping, 650 gallons per minute, gives a coagulating period of two hours. The total distance traveled by the water in this time is approximately 100 feet, so that its average velocity is 0.8 foot per minute. The water flows by gravity from the basin onto the filters, the tops of which are at approximately the same elevation as that of the basin.

Application of Coagulant.

The coagulent, aluminum sulphate, is dissolved first in a tank of about 450 gallons capacity, from which the solution flows by gravity to a storage tank holding about 900 gallons. In the latter, it is diluted to a constant strength which is tested by means of a hydrometer.

The coagulant solution is measured and applied by a small tubular pump driven by a water wheel in the discharge of the raw water pump, so that the amount used is kept approximately in direct ratio to the quantity of raw water treated. The solution pump consists of six hollow tubular arms connected to a central hollow hub, which discharges into the solution pipe through which the coagulating solution is carried by gravity and discharged into the suction of the raw water pump.

It is occasionally necessary to use lime with the alum during flood periods in the river when the alkalinity of the raw water is very much reduced. At such times, lime is dissolved in a barrel and flows by gravity into a small, cone-shaped metal tank below the operating floor. In the bottom of this tank is provided a water jet by which the solution is diluted, and in the top is an overflow from which the lime is carried by a small pipe and applied near the point of discharge of the raw water into the coagulating basin.

Filters.*

The filter plant has a nominal capacity of 1½ million gallons per twenty-four hours, and comprises 6 wooden tubs, each 10½ feet in diameter with an area of 84.0 square feet. The total filtering area is 504 square feet, or 0.01158 acre. The strainer systems are formed by brass screens supported on wooden false bottoms 16 inches above the bottom of the tubs. No gravel was used above the strainers and the filtering material consists of 22 inches of crushed quartz, having an average effective size of 0.78 m. m. and a uniformity coefficient of 1.3.

All of the piping of the filters is 8-inch wrought iron, with the exception of the drain which is of 6-inch pipe. During high stages of the river, water backs up to such a height that it is impossible to wash the filters without pumping away the dirty wash water, for which purpose a centrifugal pump is provided in the pipe gallery below the operating floor.

No loss of head gages nor automatic rate controllers are installed, but the pipe carrying the effluent from the filters to the clear well is turned up to such a height that the available loss of head for filtering is limited to 2 feet.

The filters are washed by back pressure from the clear well, and the rate of application varies with the depth of water in the well. The process of washing is assisted by mechanical agitators consisting of rakes of ¾-inch rods extending 18 inches into the sand, and which are lifted when not in use. The gutters for removing the dirty wash water are but 5 inches above the sand, and are metallic troughs 3″ wide X 5″ deep, drained by eight 2-inch pipes.

The average depth of water maintained on the sand is 5.5 feet, a fact which

*See Plate XIX

materially assists in the operation of the filters by providing a longer period of sedimentation than usual, and also by reducing the disturbing effect of currents formed by the influent.

Clear Well.

The effluent from the filters is stored in the clear well also contained inside the filter house. Its walls and bottom are of stone and concrete masonry. The area of the well is 472.5 square feet, and it has a depth of 11 feet giving a total capacity of 38,900 gallons. The minimum working depth, however, is but 4 feet, as a less depth of water in the well effects the operation of the filtered water pump. The capacity for 7 feet depth is 24,700 gallons, which, at 578 gallons per minute, gives a storage period of 43 minutes.

Pumping Plant.

The main pumping station adjacent to the filter plant is used for fire protection and contains two horizontal compound duplex Deane pumps of 1,500,000 gallons each. These are supplied by a 20-inch suction to the clear well. A 10-inch suction is also provided from the clear well across the river to the light plant in which is a direct-acting plunger pump used to lift the filtered water to the stand-pipe under ordinary conditions. It has a capacity of 1,000,000 gallons, and may be operated by either steam or water power.

Stand-pipe.

The stand-pipe is located near the filter house and consists of a steel tank 22 feet in diameter x 140 feet high, with a capacity of 398,000 gallons. It provides sufficient storage for ordinary small fires, but when the amount of water available in the tank is not sufficient, it is the custom to shut off the stand-pipe and pump directly from the clear well, using the two Deane pumps provided for this purpose. The stand-pipe serves as an equalizer, so that the filtered water pump is run at practically a constant rate, although the consumption may vary 25 per cent. during the day.

Building.

The filters, coagulating basin and clear well are housed in a substantial building, which is well lighted and where all of the various operating features are readily accessible. A fairly well equipped laboratory is provided, where a student from the high school makes occasional chemical and bacterial analyses of the raw and filtered water.

EXAMINATIONS.

During the special investigation by the State Board of Health, the plant of the Warren Water & Light Company has been visited six times as follows: May 23d, August (10-11), October (4-9), 1906, March (14-16), July 24th and December 12th, 1907. On the first and last of these visits the plant was inspected, while on the other four, regular examinations were made.

OPERATION.

When the Warren plant is in operation, water is drawn from the river by the centrifugal pump and lifted to the settling or coagulating basin, receiving the alum solution near the pump. From the settling basin, it flows by gravity through the filters into the clear well, and is pumped to the stand-pipe. The purification plant is operated by two engineers on twelve hour shifts, although frequently the plant is shut down for about two hours in the early morning. As

there is a comparatively small storage in the stand-pipe, it is necessary to keep up steam in the boilers which supply the high service Deane pumps for fire protection. In case of a severe fire the stand-pipe is bi-passed and water is pumped by the Deane pumps directly into the mains at about 125 pounds per square inch pressure. In case the filters are incapable of supplying a sufficient quantity of water during a severe fire, it is possible to replenish the quantity in the clear well by a connection to the stand-pipe.

During the special investigation daily records showing the operation of the Warren plant have been furnished the State Board of Health, and are shown in Table No. 46.

Average Daily Consumption.

The quantity of water pumped daily at Warren is estimated from the counters on the plunger pump in the light plant, by which is shown the amount actually pumped to the city. This quantity, however, does not indicate the total quantity filtered, as it does not include the water used in washing nor for condensing purposes. The average daily consumption, as shown in the daily records, is 858,000 gallons, a quantity considerably less than the maximum capacity of the plant. That the consumption is increasing, however, is indicated by the increase in the average daily consumption in 1907 over that in 1906, which, for the three months shown, is but 804,000 gallons.

Method of Applying Coagulant.

In preparing the alum solution it is customary to introduce the charge, generally a barrel of 375 pounds, into the smaller tank where it is dissolved. From this tank the solution flows by gravity into the larger tank below, where it is diluted and stored. It is the intention to keep the solution of constant strength in the larger tank, and it is frequently tested by means of a hydrometer.

From the storage tank the solution flows by gravity to the ball-cock tank in which is placed the dipper pump. The latter serves to measure the quantity of solution applied and as it is driven by a water wheel in the discharge pipe of the raw water pump, the quantity of solution taken up by the dipper pump varies with the velocity of the water in the discharge pipe. It is found, however, that on account of friction and other causes, the velocity at which the dipper pump operates does not vary exactly with the quantity of raw water pumped, but the ratio is sufficiently close for all practical purposes.

There are two available methods of varying the quantity of coagulant applied, namely, either by changing the strength of its solution, or the quantity pumped. The latter is accomplished by varying the number of arms of the dipper pump in use. In order to decrease the coagulant it is simply necessary to introduce plugs into some of the arms of the pump. In general it has been found that the method of introducing the coagulent at Warren is very satisfactory, and from the fact that the apparatus is all in sight, it is always possible for the operator to determine just at what rate the coagulant is applied.

During flood stages in the river it is occasionally necessary to add lime to the raw water in order to neutralize the alum. At such times the milk of lime is prepared in the solution tank and is discharged near the outlet of the raw water force main. Considerable fluctuations have been noted in the amount of lime applied, but the method in use serves all practical purposes, as it is intended simply to insure that no undecomposed coagulant remains in the filtered water.

From the daily records the average amount of coagulant used is 2.4 grains per gallon. The maximum daily average for a month was in June, 1907, during which time 3.3 grains per gallon were applied. When the river is very turbid

still larger quantities of coagulant are applied and the maximum amount that has been used, as indicated by the daily records, was 5.7 grains per gallon on March 14, 1907, during one of the special examinations at the plant.

Coagulating Basin.

The operation of the coagulating basin requires little discussion, although its use in preparing the water for filtration is of very great importance, particularly where the filters contain such shallow depths of filtering material as is the case at Warren. No difficulty is experienced in operating the raw water pump and filters at the same rate, so that no trouble is incurred by the overflowing of the filters.

Filters.

Numerous measurements of the rate at which the different filters were operated have been taken during the several examinations at Warren. These have indicated that the rates of the filters vary greatly from time to time, a fact which would naturally be expected in the absence of automatic rate controllers. The filtered water pump is generally operated at a constant speed, so that the rate at which the water is furnished by the filters is practically constant throughout the day. As the high water in the clear well is at the same point as the maximum elevation in the filters, it is the custom to open the discharge pipe from the filters, and to depend on the fluctuations of the water in the clear well to regulate the rate at which the filters operate. The riser on the end of the effluent pipe determines that the maximum loss of head shall not be greater than two feet and it is thus impossible to operate the filters with a negative head.

The average rate at which water is filtered, as figured from the average rate at which water is pumped, is about 75 million gallons per acre per day. This rate is occasionally largely exceeded, however, particularly during such times as the filters are washed. It is generally customary to wash all the filters at one time and one hour is required to complete their cleaning, during which time two filters are out of service, and the depth of water in the clear well decreases about 6 feet. As it is impracticable to decrease the rate at which the filtered water is pumped, it is necessary to increase the rate of operation of the filters immediately after washing, and at such times the filters are frequently operated at rates greater than 150 million gallons per acre per day. This feature is particularly unfortunate, as in order to produce the best results at Warren the rate of filtration immediately after washing should be even less than the average.

The filters are washed by a reverse current of water obtained from the clear well, and the rate of application of the wash water varies with the depth of water in the well. As all of the filters are washed at the same time, the depth of water contained in the clear well decreases so that the rate of application of the wash water falls off as the operation is continued. The average rate at which the water is applied as obtained by several measurements, is 7¼ inches vertical rise per minute for 7 minutes. The total quantity of water per wash is approximately 28,000 gallons, corresponding to 4.5 feet vertical rise.

The average quantity of wash water necessary at Warren as shown in the daily records is 4.5 per cent. The largest number of filters washed per day is 24, corresponding to approximately 72,000 gallons of water, or 8.4 per cent. At this time the river had a turbidity of about 400 parts per million.

In general it may be said that the method of washing the filters at Warren is very satisfactory, and that at all times during the examinations the sand has been found to be well cleaned.

CHARACTER OF RAW WATER.

During each of the several examinations samples of raw water have been obtained from a tap near the raw water pump. Fortunately, the examinations have covered times of both unusually high and low water in the river. As the evidence indicates a considerable variation in the character of the river water with the weather conditions, these will be discussed under the heads of the several examinations.

Examination of August 10th, 1906.

The examination on August (10-11) occurred during a period of unusually high water in the river — in fact the superintendent stated that the river was then at the highest stage ever reached except under unusual conditions. The crest of the rise in the river obtained during the night of August 10th, and the extent of the flood is indicated from the fact that there was a comparatively slow change in the chemical character of the water in the river. It is of interest to note the low alkalinity, and the necessity for lime was apparent as, during the first part of the examination, a slight amount of undecomposed coagulant was going through the filter plant. Not only was the river turbid, but the water contained also an unusually large quantity of dissolved color. The bacterial counts varied considerably, but were decreasing toward the end of the examination. One of the most interesting features noted is the absence of coli, a fact which would indicate that there is no unusual pollution of the river during periods of very high water.

Examination of October (4-8), 1906.

At the beginning of the examination on October 4th, the river was clearing up after a recent heavy rain. On October 5th and 6th, there was a very heavy rain fall, followed by a rapid rise in the river until it reached a stage that would be called normal high water for the year. It was not, however, quite as high as had obtained during the previous examination.

The changes in bacterial and chemical contents corresponding to the decline and rise of the river are of particular interest. In regard to the bacteria there was first a decrease before the rain, then a very rapid increase which attained a maximum, as did also the turbidity, before the crest of the flood had been reached. The results of the examination for coli indicate their presence only after the first severe washout following the heavy rain. Although the turbidity of the river increased and the alkalinity decreased with the rise of water in the river, the chemical changes were not so marked as the bacterial. It is interesting to note the increase in color with the rise of water in the river, and that the high color maintained longer than did the high numbers of bacteria and the high turbidity.

Examination of March 14th, 1907.

Again on March 14th, 1907, the Warren plant was examined during a period of unusually high water — in fact at this time the river was undergoing what is commonly called the spring break-up, and it reached an unusually high stage which is seldom exceeded. The river was rising at the time of the examination and the crest of the flood occurred about midnight of March 15th. It was falling rapidly on March 16th. From the fact that the bacterial count, and also the turbidity of the raw water were highest in the first samples taken, it is

apparent that the examination was begun after the crest of bacterial and turbidity increase had passed. Probably it is on this account that no coli were found in the river, as the former examination indicated that the coli occurred only during the first run-off after a heavy rain. During the highest stage of the river it contained but 12 parts per million of total carbonates. This is probably the lowest alkalinity that is reached except under very unusual conditions. As at the previous examination, it was necessary to use a small amount of lime in order to neutralize the coagulant.

Examination of July 24th, 1907.

The examination of July 24th, 1907, followed a period of continued fair weather, and the evidence indicates that, although already at a very low stage, the river was still falling. The small number of bacteria contained in the river, together with its low color and turbidity are characteristic. Its total hardness, 154 parts per million, is probably as great as is ever reached, except under unusual conditions. The coli results are of particular interest, as they were found in considerable numbers in the river, and their presence indicates considerable pollution of the river during its low stages.

Summary.

A review of the evidence obtained at the different examinations which have covered periods both of extreme high and low water, indicates that the Mahoning River at Warren is subject to very rapid and considerable changes, particularly following periods of heavy rain fall. At such times the water contains large quantities of suspended matter, considerable dissolved color, and, while the bacterial content frequently is large, there is no serious pollution except during the early periods following a heavy rain fall, and also during very low stages of the river.

The fact that the river occasionally is very soft, and even during extreme low water is not very hard, indicates that the water in the river is obtained almost entirely from surface sources and not from the ground.

The successful purification of the Mahoning River water at Warren requires that, immediately after heavy rains, and also during low stages of the river, every precaution should be observed at the filter plant, in order to obtain a potable supply.

EFFICIENCIES.

Methods of Applying Coagulant.

In general it may be said that the methods in use at Warren for the preparation and application of the coagulant have proven very satisfactory, and that no difficulty is experienced in obtaining both a constant application and any desired variations. That occasional necessity arises for the use of lime requires careful supervision during high stages in the river in order to avoid undecomposed coagulant in the filtered water, and at such times examinations are made in the laboratory at the plant to determine the alkalinities. Although the methods in use for applying the lime do not permit a very careful regulation of the amount used, they are sufficient for all practical purposes.

Some very interesting conditions were noted during the examination of March (14-16), 1907. At this time the river was in a flood stage, had a high turbidity, and at times its alkalinity decreased to but 12 parts per million. It was found that even with the use of 5 grains of coagulant per gallon, there was

a residual alkalinity in the filtered water of 3 parts per million. When tested with logwood only a trace of alum was detected in the filtered water. This would indicate that there was a very large absorption of the acid coagulant by the suspended matters in the river. Experimentally, samples were treated with two, four and six grains of alum per gallon, and although the original alkalinity was but 12 parts per million and the turbidity 400 parts per million, there was no residual coagulant with 2 grains, a slight trace only with 4 grains and about 4 parts per million of undecomposed coagulant remained in the sample treated with 6 grains per gallon. These results were obtained 24 hours after the coagulant had been added, and were checked by samples sent to Columbus.

These results are of interest, not only because they show a large absorption of alum by the suspended matter in the raw water, but also from the fact that, even with apparently excessive amounts of coagulant, there still remains three to four parts of alkalinity in the filtered water. The determinations of alkalinity were made using both methyl orange and erythrosine, and it is apparent that the presence of small quantities of undecomposed coagulant is not shown by either indicator.

It was learned that in an aquarium, supplied with city water, near the center of Warren, there are kept a large number of gold fish, and that when even very small quantities of undecomposed coagulant remain in the filtered water its presence is shown by the destruction of the fish.

It was for use during such low periods of alkalinity of the river water that the system for applying lime was provided, and as the river water is carefully watched at such times, it is probable that there are very few occasions when there remains any undecomposed coagulant in the Warren supply.

Coagulating Basin.

From the fact that the filters are composed of shallow beds of coarse sand, it is necessary to use unusual precautions at Warren that the applied water be satisfactorily prepared for filtration.

Occasionally, during periods of very low turbidity in the river, it has been found advantageous to assist the coagulation in the basin by the occasional addition of small quantities of clay. Its continued use is not necessary as no difficulty is encountered in maintaining the coagulation after it has once been well formed.

During the first examination, the Warren plant was in charge of an inexperienced operator, and the coagulation then obtained was not so good as was required, and the poor operation of the coagulating basin caused a poor efficiency of bacterial removal by the plant.

On the examination of July 24th, 1907, at which time the river was comparatively clear, several samples were taken to determine the efficiency of the basin, and it was found that its removal of bacteria was 67 per cent. In March, 1907, the results obtained by the basin show an even greater removal.

In general it may be said that, from the frequent and sudden variations of the water in the Mahoning River, an unusual degree of care is necessary in operating the purification plant in order to accomplish the best results. The coagulating basin is a principal factor in the efficiencies obtained, and, although occasionally poor, the results accomplished are generally satisfactory.

CHARACTER OF FILTERED WATER.

There has been a noticeable variation in the efficiency of bacterial removal by the filters. That they are unusually sensitive to the methods of operation of the plant is shown by the poor results obtained immediately after washing,

which may be explained by the fact that the filtering material is coarse and but 22 inches deep. After washing, it is the custom to operate the filters at unusually high rates, which is particularly unfortunate, as they are then least able to properly filter the water. To remedy this would require the installation of more filtering material of a finer grade, which in turn would necessitate raising the wash water gutters. Uneven rates are required on account of the small capacity of the clear well, and from the fact that it is not practicable to vary the rate at which the filtered water is pumped. Greater storage capacity for filtered water at the plant would materially assist its operation.

During the examinations of October (4-8), 1906, and March 14th, 1907, there were considerably greater numbers of bacteria in the filtered water at the plant than in the mains. This would indicate either that the comparatively poor results at the plant are but temporary, or that, as is also probable, the bacteria contained in the river water are largely from surface sources, and are unable to live in the mains.

That the water supply for Warren is potable has been indicated at each of the four examinations, as no coli have been found even in 100 c. c. portions of any of the samples of filtered water taken. Although the bacterial removal is occasionally poor, yet the absence of pollution, as indicated by coli, would show that these results were not necessarily significant. It is only during periods of very low water in the river, and immediately after heavy rains that coli are found in the Mahoning River at Warren; the examinations have covered both of these conditions and have shown satisfactory treatment of the water. That the water supply is potable is indicated also by the absence of typhoid fever among the consumers, as there are but very few cases of this disease in Warren and no more than would naturally be expected in a city of its size.

COST OF INSTALLATION.

The purification plant of the Warren Water & Light Company was installed in 1895. There are at present no available figures showing its exact cost. The total cost of installation of the filter house, which includes the filters and appurtenances, coagulating basin, raw water pump and clear well was $18,300.

COST OF OPERATION—1906.

In the following table is shown the total cost of operating the Warren plant for the year 1906, which, however, does not include taxes nor interest on investment. It will be noted that the salary of but one engineer is allowed, as the salary of the other is charged to maintain steam at the plant for fire protection.

LABOR		$770
1 Engineer, $60 per mo	$720	
Analyst	$50 per yr.	
PUMPING TO SETTLING BASIN (Est)		1,175
COAGULANT		1,123
10,800 lbs. alum	$1,116	
8 barrels lime	7	
INCIDENTAL EXPENSES		481
TOTAL COST OF OPERATION		$3,549
Total number of gallons pumped		293,460,000
Total cost per million gallons		$12.10

TABLE NO. 46.

Warren — Record of Operation.

Month.	Average Daily Consumption.	Gallons Filtered.	Wash Water.		Alum Used.		Turbidity of Raw Water.
			Gals.	Per cent.	Pounds.	Gr. P. Gal.	
1906.							
July	821,000	855,000	34,000	3.9	254	2.0	30
August	787,000	825,000	38,000	4.6	386	3.2	64
September	804,000	840,000	36,000	4.3	290	2.4	26
1907.							
January	879,000	926,000	47,000	5.0	375	2.8	156
February	864,000	907,000	43,000	4.7	210	1.6	165
March	880,000	938,000	58,000	5.6	406	3.0	323
April	.....	.....	.....	.....	.....	.....	.....
May	892,000	933,000	41,000	4.3	352	2.6	50
June	871,000	912,000	41,000	4.4	442	3.3	.....
July	844,000	878,000	34,000	3.8	337	2.6	23
August	929,000	979,000	50,000	5.1	238	1.7	29
September	869,000	909,000	40,000	4.4	215	1.6	26
Average	858,000	900,000	42,000	4.5	318	2.4	89

TABLE NO. 47.

Warren — Results of Analyses During Examinations.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	
	1906	A. M.								
348	8-10	6:45	Raw water	21,250	0	0	65	200	18	.....
351	8-10	9:45	Raw water	30,000	0	0	.....	.....	.....	.....
355	8-10	10:45	Raw water	.....	.....	.....	.....	220	20	.....
		P. M.								
357	8-10	2:00	Raw water	9,850	.....	.....	.....	.....	.....	.....
359	8-10	4:15	Raw water	21,000	.....	.....	60	165	18	.....
367	8-10	8:00	Raw water	15,000	0	0	.....	.....	.....	.....
		Md.								
369	8-10	12:00	Raw water	3,500	0	0	.....	.....	.....	.....
		A. M.								
371	8-11	6:45	Raw water	3,300	0	0	40	210	20	.....
352	8-10	9:45	Set. basin outlet	600	0	0	.....	.....	.....	.....
		P. M.								
358	8-10	2:00	Set. basin outlet	3,500	.....	.....	.....	.....	.....	.....

TABLE NO. 47 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	
		A. M.								
345	8-10	8:30	Effluent No. 1[1]	850	.....	.....	.....	.....	.....	.....
346	8-10	8:30	Effluent No. 2[1]	4,600	.....	.....	.....	.....	.....	.....
347	8-10	8:30	Effluent No. 3[1]	650	.....	.....	.....	.....	.....	.....
348	8-10	8:30	Effluent No. 4[1]	560	.....	.....	.....	.....	.....	.....
349	8-10	8:30	Effluent No. 5[1]	500	.....	.....	.....	.....	.....	.....
350	8-10	8:30	Effluent No. 6[1]	350	.....	.....	.....	.....	.....	.....
		P. M.								
361	8-10	4:25	Effluent No. 1[2]	360	.....	.....	.....	.....	.....	.....
362	8-10	4:25	Effluent No. 2[2]	900	.....	.....	.....	.....	.....	.....
363	8-10	4:25	Effluent No. 3[2]	1,200	.....	.....	.....	.....	.....	.....
364	8-10	4:25	Effluent No. 4[2]	900	.....	.....	.....	.....	.....	.....
365	8-10	4:25	Effluent No. 5[2]	1,000	.....	.....	.....	.....	.....	.....
366	8-10	4:25	Effluent No. 6[2]	1,000	.....	.....	.....	.....	.....	.....
		A. M.								
342	8-10	6:45	Clear well	1,500	0	0	8	1	2	.....
344	8-10	8:30	Clear well	500	.....	.....	4	1	2	.....
353	8-10	10:00	Clear well	425	.....	.....	.....	1	.....	.....
354	8-10	10:30	Clear well	300	.....	.....	24	5	3	.....
		P. M.								
356	8-10	2:00	Clear well	550	.....	.....	.....	.....	.....	.....
	1906	P. M.								
360	8-10	4:20	Clear well	1,400	.....	.....	40	2	24[3]	.....
368	8-10	8:00	Clear well	300	0	0	.....	.....	.....	.....
		Md.								
370	8-10	12:00	Clear well	350	0	0	.....	.....	.....	.....
		A. M.								
372	8-11	6:45	Clear well	250	0	0	6	2	9	.....

[1]Just before washing.
[2]Just after washing.
[3]Using lime.

TABLE NO. 47 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	CO_2
	1906	P. M.								
601	10-4	4:00	Raw water	25,000	.....	.....	40	.....	60	.....
		A. M.								
602	10-5	9:00	Raw water	11,000	0	0	.....	.....	55	.....
		P. M.								
605	10-5	3:00	Raw water	11,500	0	0	40	50	68	.....
		A. M.								
608	10-6	6:00	Raw water	2,700	.....	.....	35	50	70	.....
		P. M.								
609	10-6	3:00	Raw water[1]	2,500	+	+	43	55	74	.....
		A. M.								
612	10-7	1:00	Raw water	24,000	+	+	43	60	56	.....
615	10-7	9:00	Raw water	38,500	+	+	43	85	54	.....
		P. M.								
626	10-7	3:30	Raw water	.....	0	0	45	95	58	.....

[1]Rained during afternoon and evening.

TABLE NO. 47 — Continued.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	CO_2
627	10-7	Md. 12:00	Raw water	16,000	0	0	60	100	50	.....
630	10-8	A. M. 8:00	Raw water	19,000	+	+	60	90	41	.....
611	10-6	P. M. 5:00	Water on filter No. 1	950	.....	.....	.....	.....	.....	.....
632	10-8	A. M. 8:30	Water on filter No. 1	5,600	.....	.....	.....	.....	10	.....
600	10-4	P. M. 4:00	Tap in laboratory	260	.....	.....	2	<5	42	.....
608	10-5	A. M. 9:00	Clear well	80	0	0	0	<5	26	.....
604	10-5	P. M. 2:30	Tap in laboratory	15	0	0	2	<5	37	.....
607	10-6	A. M. 6:00	Clear well	28	.....	.....	6	<5	41	.....
606	10-6	P. M. 3:00	Tap in laboratory	38	.....	.....	3	<5	40	.....
618	10-7	A. M. 1:00	Clear well	51	0	0	2	<5	27	.....
616	10-7	9:00	Tap in laboratory	175	0	0	5	<5	26	.....
617	10-7	11:00	Clear well[2]	3,300	0	0	2	<5	30	.....
618 to 623	10-7	M. 12:00	Average of Effluents (1-6)	58	.....	.....	.....	.....	.....	.....
625	10-7	P. M. 3:00	Tap in laboratory	130	.....	.....	2	<5	26	.....
628	10-7	Md. 12:00	Clear well	15	.....	.....	0	<5	12	.....
631	10-8	A. M. 8:00	Tap in laboratory	.....	.....	.....	0	<5	8	.....
633	10-8	9:00	Tap in laboratory	65	.....	.....	.....	.....	.....	.....
610	1906 10-6	P. M. 2:00	Tap at Park hotel	28	.....	.....	6	<5	46	.....
614	10-7	A. M. 8:30	Tap at Park hotel	25	0	0	2	<5	41	.....
624	10-7	P. M. 2:00	Tap at Park hotel	28	0	0	2	<5	36	.....
629	10-8	A. M. 6:15	Tap at Park hotel	48	0	0	2	<5	28	.....
1098	1907 8-14	A. M. 9:00	Raw water	70,000	0	0	45	500	17	.....
1099	8-15	P. M. 2:00	Raw water	49,000	0	0	45	400	12	2
1094	8-14	A. M. 9:00	Set. water top No. 5	6,300	0	0	.....	.....	8	.....
1100	8-15	P. M. 2:00	Set. water top No. 5	3,300	0	0	.....	50	16[3]	.....
1092	8-14	A. M. 8:30	Tap in laboratory	375	0	0	5	<5	8	.....
1096	8-14	11:00	Tap in laboratory	350	0	0	5	<5	8	.....

Incrustants, Samp. No. 630, 35; Sample No. 631, 60.
[2]After washing.
[3]Using lime.

TABLE NO. 47 — Concluded.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	CO_2
		P. M.								
1098	3-15	1:30	Tap in laboratory.....	1,900	0	0	6	<5	4	14
1102	3-15	4:30	Tap in laboratory.....	900	.....	.....	6	<5	3	.....
		A. M.								
1095	3-14	9:00	Clear well	325	0	0	5	<5	3	.....
		P. M.								
1101	3-15	2:00	Clear well	450	0	0	6	<5	3	17
		A. M.								
1091	3-14	8:00	Tap at Park hotel.....	325	0	0	0	<5	3	.....
		P. M.								
1097	3-15	1:00	Tap at Park hotel.....	4	0	0	8	<5	6	.....
		A. M.								
1105	3-16	8:00	Raw water	36,000	0	0	30	260	12	.....
1106	3-16	8:00	Set. water top No. 5.....	5,700	0	0	.....	90	4.5	.....
	1907	A. M.								
1104	3-16	7:30	Tap in laboratory.....	9	0	0	5	<5	6	.....
1108	3-16	10:00	Tap in laboratory.....	1,100	0	0	6	<5	5	.....
1107	3-16	8:00	Clear well	880	0	0	5	<5	4.5	.....
1103	3-16	7:00	Tap at Park hotel.....	275	0	0	5	<5	6	.....
		A. M.								
532	7-24	7:30	Raw water	800	+	+	20	17	114	.....
537	7-24	11:30	Raw water	.....	0	+	20	.....	114	2
		P. M.								
542	7-24	3:30	Raw water	425	+	+	.....	20	116	.....
			Average	613	.....	.....	20	19	115	2
		A. M.								
533	7-24	8:00	Set. water No. 1.....	50	.....	.....	.....	13	98	.....
		M.								
538	7-24	12:00	Set. water No. 1.....	400	0	+	.....	12	100	14
		P. M.								
543	7-24	4:00	Set. water No. 1.....	350	+	+	.....	15	102	.....
			Average	267	.....	.....	.....	13	100	14
		A. M.								
534	7-24	8:00	Clear well	32	0	0	10	<5	98	.....
535	7-24	10:00	Clear well	16	0	0	10	<5	101	11
		M.								
539	7-24	12:00	Clear well	100	0	0	10	<5	101	.....
		P. M.								
540	7-24	2:00	Clear well	90	0	0	10	<5	98	13
544	7-24	4:00	Clear well	120	0	0	10	<5	104	.....
			Average	72	0	0	10	<5	100	13
		A. M.								
531	7-24	7:30	Tap at laboratory	25	0	0	10	<5	98	.....
536	7-24	11:30	Tap at laboratory	110	0	0	10	<5	101	9
		P. M.								
541	7-24	3:30	Tap at laboratory	150	0	0	10	<5	101	.....
			Average	95	0	0	10	<5	100	9

Incrustants, Samp. No. 542, 38; Samp. No. 544, 56; Samp. No. 541, 54. Chlorine, Samp. No. 541, 4.7; Samp. No. 544, 3.0.

YOUNGSTOWN.

The city of Youngstown is in the northwestern portion of Ohio in Mahoning County on the Mahoning River. In 1905 its population was estimated at 60,000, of which the percentage of foreigners was very large, due to the many large steel and iron industries. The city ranks as one of the foremost in the middle west in its manufacturies and is occasionally referred to as the "New Pittsburg."

HISTORICAL.

Original Installation.

The waterworks were originally installed in 1872, and until 1903 the supply was taken directly from the Mahoning River without purification. During this period the city had an unusually high death rate from typhoid fever — in fact, the rate of deaths from this cause was one of the highest of any city in the United States. While it was not thought that all of the typhoid was necessarily to be attributed to the water supply, yet it was appreciated that this was an important feature in the causation of the disease. Not only was the water unwholesome, but the Mahoning River at times contained objectionably large amounts of suspended matter and color, and was not well adapted for domestic use.

Conditions Leading to Purification.

On account of the unwholesomeness of the Mahoning River, several consulting engineers were employed from 1899 to 1903 to investigate all available sources, among which were considered the continued use of the Mahoning River after purification; ground water sources; Mill Creek with necessary storage and purification; and Meander and Mosquito Creeks. The conditions influencing the quality of the Mahoning River water were briefly stated in a report submitted by one of the consulting engineers, Mr. George W. Fuller, in September, 1903, to be as follows: "At present the city of Youngstown is supplied with raw water taken from the Mahoning River and pumped directly into the city mains. The intake is situated about half a mile above the dam at Baldwin's Mill, and about midway of the length of the pool created by that dam. The pumping station and intake are below several of the large steel mills. On the north side of the river the built-up section of the city extends a considerable distance above the intake. Within the limits of the city of Youngstown there is no serious pollution due to the direct entrance of sewage matter into the Mahoning River, although it is true that the surface drainage of a considerable area reaches the river at times of storms.

"The watershed of the Mahoning River, about 960 square miles in area, drains a rich and prosperous country, on which there are situated the towns and cities of Girard, Niles, Warren and Alliance, which had a population in 1900 of 2,630, 7,468, 8,529 and 8,974, respectively, according to the U. S Census Reports. Girard is situated five miles above the intake, and has no sewerage system. Niles is ten miles above the intake, and has very limited sewerage, the population there connected to sewers being estimated at less than 1,000. At Warren, 16 miles above the intake, the population sewering directly into the river is estimated at less than 5,000. At Alliance, 62 miles above the intake, it is said that fully as many are connected with the sewers as at Warren, but there the sewage undergoes partial purification by chemical precipitation before it reaches the river. In addition to these partially sewered cities there are about half a dozen villages with a

population from 500 to 1,000 each, some 50 small villages having an average population of about 100, and quite a number of industrial establishments which discharge manufacturing waste into the river.

"The Mahoning River water ordinarily is noticeably turbid from silt and clay, and at times decidedly so. In the pool from which the water is taken are the intakes of several of the large steel works, which during dry weather pump over and over again a portion of the water, adding to it ore dust and some oil from machinery. Both from inspection and from the results of various analyses which are on record of the Mahoning River water, it is obvious that this water is dirty and polluted to a degree which unfits it in its raw condition for satisfactory use as a municipal water supply."

In all of the reports submitted by the consulting engineers, it was recognized that no suitable supply could be obtained without purification. It was shown in Mr. Fuller's report that the use of the Mahoning River could be continued for several years with suitable purification, but that eventually when the water consumption increased to an amount exceeding 8,000,000 gallons per day, as would probably occur in 1915, it would be necessary to increase the amount available by an additional supply; that while the Mahoning River water was dirty and unsightly it was made so largely by surface washings from the ground, and by manufacturing refuse of a nature which can be readily removed, rather than by domestic sewage. By previous investigations of the State Board of Health, it appeared to be shown that there was no more organic matter in the river above Youngstown than above Alliance, and a comparison of the averages of available analyses of the Mahoning River at the intake with those of Mill and Meander Creeks would indicate that there was no substantial difference in the quality of the water from these various sources, as to organic matter contained.

It was eventually decided to install a purification plant of 10,000,000 gallons capacity, using the Mahoning River as a source. The site selected was the city's property across the river from, and 500 ft. above the pumping station, to which point water could be carried by gravity from any source used for the future extension of the supply. It was hoped that satisfactory water could be obtained in this manner until 1915, after which time it would be necessary to increase the available supply from a source not definitely determined.

DESCRIPTION OF PLANT.

The purification plant was built in 1905, and comprises the following features: An intake of special design about 500 feet above the old pumping plant; a low service pumping plant; two coagulating basins; a system for dissolving and applying the coagulant; twelve concrete gravity mechanical filters; a concrete covered basin for storage of filtered water; together with the necessary mains for carrying the clear water to the old pumps, which were still used to pump water into the distribution system and standpipes. The filters and coagulating basins are contained in a substantial building just north of which is the clear well. (See Plate XX.)

Intake and Raw Water Pumps.

The intake extends 20 feet into the river and consists of a rock-filled timber crib in which are laid five 12-foot lengths of 20-inch pipe. Pipe nozzles connected with a 6-inch main carrying water under the usual pressure of 90 pounds are provided in the shore end of these pipes for flushing purposes. The 20-inch pipes discharge through a screen into a 4-foot brick conduit divided by a horizontal partition of oak plank into two compartments, which are also flushed by nozzles. The conduit discharges into a brick suction well, in which are two 24-inch

cast-iron suction pipes leading to the raw water pumps. The latter are low service centrifugal pumps, in duplicate, of 10,000,000 gallons capacity each, built by the William Tod Company. The discharge main from these pumps is a 30-inch cast-iron pipe leading to the coagulating basins and entering each basin at the inner corner next to the pump and coagulating room.

Coagulant.

The coagulant used is the Excelsior brand of aluminum sulphate obtained from the Pennsylvania Salt Manufacturing Co. of Philadelphia. It is shipped in barrels containing 375 pounds each.

Means for Applying Coagulant.

The coagulant solution is prepared and stored in two wooden tanks, 8 feet in diameter by 8 feet deep of 3,000 gallons capacity each. In the bottom of the tanks are systems of small pipes carrying compressed air for agitation. Two-inch brass pipes carry the solution to a regulating tank which contains an adjustable orifice. A constant head is maintained on this orifice by a ball-cock and the application is varied by changing the size of the orifice. From the tank, the solution is carried by a 2-inch brass pipe and introduced into the suction of the raw water pumps.

Coagulating Basins.

The inlets of the coagulating basins consist of horizontal wooden troughs 2x4x20 feet long, resting on iron brackets built into the concrete inside wall of the basins about half way up from the bottom. Longitudinal spaces are left between the planks of the troughs to distribute the flow of the incoming water, which is controlled by gate valves.

There are two coagulating basins, separated by a gravity concrete wall. They are well baffled and the average distance traveled by the water is about 124 feet. Each basin is 63.5 feet by 58 feet by 20 feet deep, with a total capacity in each compartment of 550,000 gallons, which at the maximum rate of pumping, 10,000,000 gallons per day, gives a period of 2 hours and 39 minutes coagulation with an average velocity of 0.78 foot per minute through the basins. The bottom of each basin has a slope of 6 inches to the point opposite the inlet, where is located the 12-inch drain. The outlets of the basins are located opposite the point of entrance and consist of horizontal metal plates or weirs 21.5 feet long, attached to the concrete walls by bolts fitted in slotted holes, which permit an adjustment of the height of the outlets.

Filters.*

The discharge from the coagulating basins flows over the outlet weirs into concrete channels and is applied to the filters through the wash water troughs. The filters are 12 in number and consist of concrete tanks approximately 16.5 x 22.0 feet in plan at the top. The area at the sand is 319 square feet, which gives a total area of 3828 square feet or 0.0879 acre. At 125,000,000 gallons per acre per day the nominal capacity of the plant is 10,900,000 gallons. In the bottoms of the filters are located the strainer system, consisting of manifolds of 1½-inch wrought iron pipes, 6 inches center to center, into which are screwed at 6-inch intervals brass strainers of the Deutsch design.

Wash water is furnished by a 4,000,000 gallon centrifugal pump, the suction of which is directly connected to the main collector carrying the effluent from the filters. Agitation to assist in washing is furnished by air, which is carried to the filters in 4-inch pipes, and introduced into the main collectors at three points.

*See Plate XXII.

Youngstown. — Exterior of Filter House.

Youngstown. — Interior of Filter House.

The air mains are of 4-inch wrought iron, and the pressure applied can be varied from 2½ to 4 pounds per square inch. The air is furnished by a 14x36x18-inch Laidlaw Dunn-Gordon straight line compressor.

The gutters for carrying away the dirty wash water are formed by ¼-inch steel plates 24 inches wide, bolted to an off-set in the side walls of the filters. The troughs are 15 inches deep by 12 inches wide, and the crests of the weirs are 15 inches above the sand. As there are no central gutters, the water has to travel a maximum distance of 7 feet 3 inches, and it was found that this distance was too great, as the heavy particles carried by the wash water settled back onto the sand and did not reach the gutter. To give the water at the center of the bed an additional velocity, a heavy wrought iron pipe perforated with a large number of small holes on the horizontal axes has been placed down the center of each filter, at the height of the crest of the gutter. These pipes carry water under approximately 90 pounds pressure, which is turned on during washing, giving a horizontal jet over the surface of the water in the filter. This materially assists in carrying away the dirty water from the center during washing. That their effect is considerable is shown by the fact that the sand has gradually assumed a depth of about 2 inches greater on the sides of the filter than at the center.

The depth of water generally carried on the sand is about 30 inches, and may be varied by the setting of the weirs controlling the discharges of the coagulating basins.

The filtering material consists first of a 9-inch layer of screened gravel, on which is placed 36 inches of filter sand, which was obtained from Sea Girt, N. J. The effective size of the sand is 0.40 m. m. and its uniformity coefficient 1.3.

Although loss of head gages and rate controllers were included in the original plans, they have never been installed, and in the absence of the latter, the filters are controlled entirely by the valves in the discharge pipes.

Clear Well.

From the filters the water flows by gravity into a 30-inch cast iron main leading to the clear well, which is outside of and about 125 feet north of the filter house. The well is 84 feet in diameter, and 20 feet deep, with a total capacity of 665,000 gallons, which, at 10,000,000 gallons per 24 hours, gives a storage period of 96 minutes. It is built of concrete and covered with a conical steel-truss roof, supported without posts. The 36-inch main carrying the filtered water from the clear well to the pumping station is double-strength cast iron with lead joints, and is laid across the river on the bottom.

From the fact that open float tubes are connected to the effluent pipes of each filter and that the suction of the wash water pump is connected to the main effluent pipe, it is impossible to operate the wash water pump when the depth of water in the clear well is less than 14'-8". This reduces the working depth of the clear well to four feet.

Filter Building.*

The filters, raw water pumps and machinery, and coagulating basins are installed in one building, the sub-structure of which is of concrete, and the superstructure of brick. The building is covered with a steel-truss slated roof, and while it does not present a particularly attractive appearance from the outside, partly on account of its surroundings, yet the various rooms are well lighted and the filter room in particular presents a rather attractive appearance. The only visible features are the basins, filters and the operating stands for their control. One of the important features of the plant is the laboratory where regular bacterial and chemical analyses are made daily by a competent analyst.

*See Plate XXI.

Pumps and Storage.

The pumps which handle the filtered water consist of one horizontal compound duplex Deane pump, built in 1884, and two horizontal compound duplex Tod pumps of 5,000,000 gallons capacity each, built in 1897. The total pump capacity is 15,000,000 gallons.

The distribution system of Youngstown is divided into a high and low service. The latter is supplied by a direct pump pressure of 100 pounds without any storage, while the former is supplied by a separate pump and contains two stand-pipes, one on the north and one on the south side, each 30 feet in diameter and 100 feet high, with a combined capacity of 1,000,000 gallons.

EXAMINATIONS.

During the special investigation by the State Board of Health, the plant has been visited six times, on May 23rd, July (16-20), October (1-6), 1906, March (11-15), April (19-30), December 12th, 1907. Regular examinations were made except on the first and last of the above visits, when the plant was inspected.

The examination of April (19-30), 1907, was undertaken in order to determine not only the efficiency of the plant, but to ascertain the number of coli in the raw water, and also the value of lactose bile media for the determinations of coli.

OPERATION.

The filtration plant is in charge of a superintendent, who also makes a number of daily chemical and bacterial examinations of the raw and filtered water. He is assisted by three engineers, three firemen, three filter attendants, one assistant machinist, and one janitor. It will be seen that this force is unusually large and contributes largely to the expense of operation of the plant.

When the filtration plant is in operation, water flows by gravity from the river into the pump well or forebay, from which it is lifted by the low service pumps into the coagulating basins, receiving the coagulant solution near the suction of the pumps. From the coagulating basins the water flows by gravity through the filters into the clear well, and is pumped into the distributing system. On account of the small storage provided it is necessary to operate both the filter plant and pumping station during the entire day. There is a considerable hourly variation in the consumption in the low service districts, and also it is the custom to pump filtered water to the stand-pipes three times during the day, so that the hourly quantity of water filtered varies considerably.

During the special investigation copies of the daily records showing the operation and efficiency of the Youngstown plant have been furnished the State Board of Health by the superintendent. Monthly averages of these daily determinations are shown in Table No. 49.

Average Daily Consumption.

The average daily consumption for the last ten months of 1906 was 5,517,000 gallons. The average daily consumption during the entire year of 1907 was 6,075,000, which shows a yearly increase of 560,000 gallons. This increase is of interest, as the total quantity of water available in the Mahoning River during the driest months has been estimated at but approximately 8,000,000 gallons per day, and it would appear that in 1910 this quantity will be equaled by the average daily consumption. As it is well known that the average daily consumption is

frequently exceeded by 50 per cent. on a few days during the year, this question is of great importance, and indicates the immediate necessity of securing an additional supply.

On the examination of December 12th, 1907, it was learned that the feasibility of increasing the flow in the Mahoning River during the dry season was being investigated by the city engineer. The plan proposed provided for a storage reservoir at Berlin, about 20 miles above the present waterworks. The quantity impounded will be approximately 5.3 billion gallons, and for this purpose it will be necessary to construct a masonry dam to a height of about 50 feet above the present level of the river bottom. Not only would this plan provide a sufficient flow in the river for purposes of water supply for Youngstown, but it would also materially assist in the development of large manufacturies which depend for their existence on a constant supply of large quantities of water.

Methods of Applying Coagulant.

The method of applying the coagulant at Youngstown has been the same during the investigations. In preparing the coagulant solutions a charge of alum, generally 990 pounds, is introduced into a perforated box in the top of the storage tanks, through which box water is introduced from a connection to the force main carrying filtered water. When the storage tank is full, the coagulant is submerged and is generally dissolved in about one hour. The tanks are used alternately and the solution is prepared in the one while it is running out of the other.

From the storage tanks the solution flows by gravity to a regulating tank. The discharge from this tank is controlled by an adjustable orifice on which a constant depth is maintained by a float valve which controls the inlet. From the regulating tank the solution flows by gravity and is introduced into the suction near the raw water pump.

Although air for agitation is provided in the tanks and is nominally applied at about 30-minute intervals, it has not proven efficient, as was shown by determinations of the specific gravity of the solutions by a hydrometer.

The actual available depth of the solution in the tanks is 90 inches, and as each charge is 990 pounds, one inch of solution contains 11 pounds of alum. It is generally the custom to so regulate the application of the coagulant that one inch of solution, or 11 pounds, is applied every hour for each filter in service. There are two methods for varying the quantity of coagulant used, as it is possible either to change the charge dissolved in the tanks or the number of inches of solution applied. The maximum quantity that it has been found practicable to dissolve in the tanks is 1980 pounds, and the maximum rate of application is 1½ inches of solution per hour per filter.

Quantity of Coagulant Applied.

On account of the polluted character of the raw water, it is necessary to use considerable quantities of coagulant for its purification. The average daily quantity used, as shown in the daily records, has been 2.76 grains per gallon during the last ten months of 1906, and 2.61 grains per gallon, the average of the entire year of 1907. Occasionally, it has been found necessary to temporarily increase the quantity of coagulant applied and during the examination of March 13, 1907, 5.07 grains per gallon were used for about 24 hours. At this time there occurred a rapid change in the character of the river water, which change was caused by very heavy rains.

Coagulating Basins.

Although the operation of the coagulating basins requires but little attention, it has been found at Youngstown, as at all other Ohio plants, that the satisfactory operation of the plant depends largely upon obtaining efficient results by the basins, or upon the proper preparation of the water for filtration. The average quantity filtered daily during 1907 has been 6,377,000 gallons, and as the basins have a total capacity of 1,100,000 gallons, the average period of coagulation has been 4.1 hours. This figure is based on the assumption that all of the filters are operating at equal rates during 24 hours. Practically however, there is a considerable variation in the quantity of water filtered during different periods of the day, and corresponding variations in the actual period allowed for the coagulation of the water.

The variations in the quantity filtered are due to the fact that three times daily filtered water is pumped to the stand-pipes, namely at 8:00 A. M., 5:00 P. M. and 12:00 Md. The following table shows the varying rates of filtration as occurred during the examination of December 12th, 1907, and also the corresponding periods of coagulation:

Time.		Rate of Filtration.*		Coagulating Period (Hours.)
From	To	Gallons per 24 hours.	Gallons per Min.	
8 A. M.	11 A. M.	10,000,000	6,950	2.6
11 A. M.	4 P. M.	6,000,000	4,170	4.4
4 P. M.	6.30 P. M.	10,000,000	6,950	2.6
6.30 P. M.	12 Md	4,500,000	3,130	5.9
12 Md.	2 A. M.	10,000,000	6,950	2.6
2 A. M.	8 A. M.	3,500,000	2,430	7.5

* The average rate from the above figures is 6,300,000 gallons per day.

It is generally the custom to clean the coagulating basins at least once every six weeks. On the morning of July 20th, 1906, settling basin No. 2 was cleaned. It was found to contain approximately 6 feet of mud that had accumulated during 50 days previous operation during which time the average quantity of water passing through the basin daily was three million gallons. The mud which had accumulated flowed readily through the drain except the lower 6 inches, which was readily flushed through the drain by means of water applied from a fire hose. The total operation of cleaning the basin, including its draining and flushing out of the mud, was completed in four hours.

Filters.

Rate of Filtration.—As has been discussed in the report of the Marietta plant, there is a difference of opinion in regard to whether the best results are obtained by operating all of the filters all the time and by changing the quantity filtered by varying the rates of filtration, or whether better results can be obtained by maintaining approximately constant rates of filtration and varying the output of the plant by changing the number of filter units in service. The former method has been used at Marietta and the latter at Youngstown.

The filters are not provided with automatic rate controllers, but the operators are so experienced that they are able to tell by the appearance of the ripples in the water on the surface of the filters approximately at what rate the filters are operating. The rate of filtration is determined by the degree of opening of the valves in the effluent pipe, and has been found very nearly constant during the several examinations. A record is kept of the total number of filters in service each hour, from which record the average number of filters used during the day is computed. The average rate of filtration is determined by dividing the total quantity filtered by the average filtering area in service during the day, and in this manner it has been found that the average rate of filtration is very nearly 100 million gallons per acre per day. This estimate of the rate has been practically constant during each of the several examinations.

Washing.—No loss of head gages are provided to indicate when the filters are dirty, and it is generally the custom to wash them at regular intervals; in this manner, six filters are washed at about 8-hour intervals, giving a total of 18 washes per day.

As the wash water is supplied by a separate pump, its rate of application is readily controlled, and during the latter part of the investigation the average rate has been 2,100 gallons per minute for 8 minutes, corresponding to 16,800 gallons per wash, or 7.0 vertical feet. At 18 washes per day the total quantity of wash water used is 302,000 gallons, which corresponds to 5.0 per cent of the total quantity of water filtered. The quantity filtered is greater than the average daily consumption, which figure does not include the quantity of water used for washing.

The above quantities of wash water are figured on the assumption that the rate of application is constant and is determined by the rate of discharge of the wash water pump. While it is true that the total quantity of water discharged by the wash pump is 2,100 gallons per minute, the actual distribution to the filters, several of which are washed at the same time, is different from the average, as it has been found most efficient to wash them slowly at first, increasing to the maximum rate, and then to gradually shut off the wash water and complete the wash at about one-half the maximum rate.

As has been shown, both the wash water and air used for agitation are applied in the same piping and considerable difficulty was experienced in obtaining a proper distribution of the air until the best method for its application was determined. The filters were poorly washed during the months of June and July, 1906, on which account numerous hard spots accumulated in the sand, particularly at the surface. These hard spots tend to cause uneven rates of filtration and there resulted a marked decrease in the efficiencies of bacterial removal. The method of washing then in use was as follows:

1st.—Drain the filters to a point about 3 or 4 inches below the top of the gutter.

2d.—Turn on the air at a pressure of 5 pounds for 5 minutes.

3d.—Stop the air and turn on the wash water for 10 minutes.

4th.—Shut off the wash water, close drain, open influent and allow the filter to stand idle a little while, if possible.

5th.—Start filter, but at slower rate than usual.

6th.—After about 30 minutes run the filter at the usual rate.

With this method it was found that the air was very poorly distributed and came through the sand very much faster in certain spots than in others. Occasionally, both the sand and the water were blown to a height of two feet above the level of the water in the filters, and the underdrain gravel was forced through the sand to the surface. This poor application of the air was largely the

cause of the accumulation of the hard spots in the sand, and it was to improve its distribution that a new method of washing the filters was tried as follows:

1st.—Drain the filter entirely dry.

2d.—Turn on the air for about two minutes.

3d.—Fill the filter from above with coagulated water.

4th.—Turn off the air and turn on the wash water immediately, not allowing any dirty water to go down through the filters.

The remainder of the procedure of washing is the same as that formerly used.

The hard spots in the filters were readily apparent with this new method of washing, and were eventually removed by working over the sand with a bar and also by using a screened dipper by which the coarser particles deposited on the surface were removed. This new method of washing has been found very satisfactory, and its use has been continued since July, 1906.

CHARACTER OF RAW WATER.

During the several examinations of the Youngstown plant, samples of the raw water were taken from a tap in the laboratory. Water was pumped to this tap by a small sampling pump, the suction of which was connected to the main suction of the raw water pump. As considerable variation was found in the character of the water in the river, corresponding to changes in the weather conditions, the results obtained at the different examinations will be discussed in turn.

Examination of July (16-20), 1906.

The examination in July, 1906, was during a period of continued fair weather and the evidence indicates that the river was clearing up, as is shown by the decrease in turbidity and bacterial content. There had been a recent rain, and it is of interest to note the rapid change in the character of the raw water.

Examination of October (1-6), 1906.

On the day before the examination in October, 1906, there had been a very heavy rain, and a sudden change in the character of the raw water is indicated by the rapid increase in turbidity and bacterial content, and the decrease in hardness. There was also a considerable increase in dissolved color, which continued for some time after the crest of the rise in the river had passed, and the raw water had begun to clear up.

Examination of March (11-15), 1907.

A severe storm began during the evening of March 12th, and continued for a greater part of two days. This caused a very rapid rise of the water in the river, which reached a maximum stage at midnight on March 14th, when the water had risen to a point about one foot higher than at any time during the past year. This height represents the normal high water of the year, and is only exceeded during extreme floods. The evidence indicates a very rapid increase in the turbidity of the river, and a corresponding decrease in its hardness. Although the bacterial content increased also, the maximum number was considerably less than had occurred during the preceding examination. This was due to the fact that there was a greater dilution, and that, as the ground was frozen, there was a less quantity of surface wash. The coli results during this examination are significant as they indicate considerable pollution in the river.

The alkalinity on March 14th, 14 parts per million, is probably as low as ever occurs during the year.

Examination of April (19-30), 1907.

Fair weather prevailed at the beginning of this examination, but on April 23rd a heavy rain began at noon and was followed by a steady rise of the river at a rate of about 3 feet in 24 hours. The rain stopped during the night of April 24th, but began again at 2:00 P. M. on April 25th, and continued until 11:00 A. M. April 26th. The river continued to rise until about noon of April 27th, when it became stationary after a rise of possibly 9 feet. There was a corresponding increase in the turbidity until April 27th when the maximum reached was 200 parts per million at approximately the same time as the crest of the flood. The maximum bacterial content of the river, 65,000 per c. c., was obtained at 3:00 P. M. on April 24th, and was followed by a slight decrease during the remainder of the examination.

During this examination studies were made of the value of lactose bile media for determinations of coli, and the number of coli in the raw water was estimated by using different dilutions of the bile media. The value of the media has been discussed on Page 49. The evidence obtained at this examination indicates that it is a much more efficient and delicate media than Smith solution.

In Table No. 48 are shown the number of samples tested, the dilutions, and the results of the confirmatory tests for coli using the bile media and carrying the tests through to gelatin as recommended in "The Report of The Committee on Standard Methods of Water Analyses." These results indicate a large increase in the number of coli contained in the raw water following the rain of April 23.

TABLE NO. 48.

Results of Confirmatory Tests for Coli.

Date.	Raw Water.				Filtered Water.			
	No. of Samples Tested.	No. of Positive Tests and Quantity of Water Used.			No. of Samples Tested.	No. of Positive Tests and Quantity of Water Used.		
		0.1 c. c.	0.5 c. c.	1.0 c. c.		1.0 c. c.	5.0 c. c.	10.0 c. c.
April 20	12	(Not in 0.05 c. c.)			12	0	0	2
April 22	10	3	.....	.....	10	0	1	1
April 23	1	0	1	1	1	.....	.....	0
April 24	12	7	12	12	12	.....	.....	3
April 25	2	1	2	2	1	.....	.....	0
April 26	1	1	1	1	1	.....	.....	0

Summary.

The evidence obtained during the several examinations shows that the Mahoning River at Youngstown always contains sufficient suspended matter to make it unsatisfactory for domestic use, and that it is subject to very sudden changes following heavy rains. At such times the quantity of suspended matter contained is very largely increased, and there is also a rapid increase in the bacterial content due to surface washings of an objectionable nature.

In the daily records it is shown that the river always contains very large numbers of bacteria and also considerable pollution as is indicated by the high percentage of positive tests for coli. The average turbidity for the two years

is 60 parts per million, and the average dissolved color for 1907, 35 parts per million. The evidence indicates that the satisfactory purification of the Mahoning River at Youngstown requires unusual care in the operation of the filter plant in order to secure a potable supply. This fact has been of great importance in determining the cost of operation of the purification plant, as it has been necessary to use unusually large quantities of coagulant in order to obtain the high bacterial removal necessary on account of the pollution of the river.

EFFICIENCIES.

Guarantee.

The contract covering the construction of the plant contains the following guarantee:

"The filtered water will be free from odor, will be bright and clear and free from matter in suspension and color visible to the naked eye.

"When the number of bacteria in the raw water exceed 3,500 per cubic centimeter, there shall be an average reduction of the bacteria in the filtered water from the whole plant in use of 98 per cent. When the raw water contains less than 3,500 bacteria per c. c. the average number of bacteria in the filtered water from the whole plant in use shall not exceed 75 per c. c. When the bacteria in the raw water exceed 3,500 per c. c. not more than 5 per cent. of the samples from the whole plant nor more than 10 per cent. of the samples from a single filter shall show a reduction of less than 90 per cent. as compared with the raw water. When the number of bacteria in the raw water are less than 3,500 not more than 5 per cent. of the samples from the whole plant nor more than 10 per cent. of the samples from a single filter shall show more than 100 bacteria per c. c. in the filtered water.

"The filtered water shall contain no undecomposed coagulant and no more iron or aluminum than the applied water. It shall not show an acid reaction nor an alkalinity greater than the raw water.

"The contractor shall fulfill all rules and requirements of the State Board of Health.

"Wash water shall not exceed 5 per cent. of total water filtered."

Intake.

The intake of the filtration plant has proven very satisfactory. It is occasionally found desirable to flush out the sediment that accumulates in the pipes, which flushing is accomplished by means of the nozzles previously described. On the morning of July 19th, 1906, the intake was flushed out and a sufficient quantity of red mud removed to cause a very marked increase in the turbidity of the water in the river.

Methods of Applying Coagulant.

The methods of preparing and applying the alum solution have proven satisfactory and provide an easy regulation of the coagulant. On account of the numerous changes in the rate of pumping and filtering the water, however, it is necessary to vary the rate of application of the coagulant several times a day, and on account of the considerable storage in the coagulating basins, the rate of application of the alum does not vary exactly with the rate at which water is filtered. This fact is shown by the variations in the alkalinity of the filtered water. It would be desirable to provide some means of introducing the coagulant whereby its application could be varied to correspond more accurately with the rate at which water is pumped to the coagulating basins.

Several interesting features developed during the examination of March (11-15), during which time there occurred a heavy rain, and a consequent rapid rise in the river. In order to secure the necessary bacterial efficiency by the plant, unusually large quantities of alum were used. The actual quantities of alum applied together with the corresponding alkalinities of the raw and filtered water during this examination are shown in the following table. The last column of this table contains the reduction of alkalinity in the treated water corresponding to one grain of alum applied. On March 14th, although the river had an alkalinity of but 14 parts per million and 5 grains of alum per gallon were applied, there was a residual alkalinity of 3 parts per million in the filtered water and the corresponding reduction in alkalinity per grain of alum applied was 2.2 parts per million. The alkalinities were determined using both methyl orange and erythrosine as indicators, and both gave similar results. On March 14th the filtered water was tested for alum using logwood as an indicator, and it was found that it contained but 6 parts per million of alum.

These results are of particular interest as they indicate a very large absorption of alum by the suspended matters in the river water, and also that neither methyl orange nor erythrosine are of value in determining the presence of undecomposed alum when present in small quantities. The titrations were repeated on samples after standing thirty-six hours, and the results then indicated that the water was neutral to both methyl orange and erythrosine.

ALUM USED AND CORRESPONDING ALKALINITY REDUCTIONS.

Date. (1907)	Alkalinity.*		Turb.*	Alum Used.	Red. Alk.
	Raw Water.	Filtrate.	Raw Water.	Gr. p. Gal.	P. Gr. Alum Used.
March 12	65	42	70	3.45	6.1
March 13	24	13	375	5.07	2.2
March 14	14	3†	375	5.00	2.2
March 15	15	3	400	4.70	2.3

* Parts per million.
† Contained 6 parts per million of Alum by test with logwood.

The above facts indicate that a considerable saving in the use of alum would be accomplished by a provision for its secondary application during periods of high turbidity in the river, as there is a large absorption of the coagulant at such times. By allowing a partial deposition of the suspended matters before the total necessary amount of alum is applied, this absorption would be decreased. The results also indicate that the presence of alkalinity in the filtered water does not signify that it contains no undecomposed alum. On account of the occasional necessity for using large quantities of coagulant, some means should be provided by which lime can be introduced in order to prevent the appearance of alum in the filtered water.

Coagulating Basins.

It has been shown on page 288 that there is a considerable variation in the hourly quantity of water filtered during the day and in the coagulating period in

the basins. During the several examinations frequent analyses of the filtered water indicate that there are considerable variations in the bacterial efficiencies obtained by the plant and that the maximum efficiencies of the filters follow the maximum period of coagulation in the basins. The results indicate a close relation between the efficiencies obtained by the basins and by the entire plant.

On March (13-14), 1907, 5 grains of coagulant per gallon were used, and there was a bacterial removal by the basins of 90 per cent. and a corresponding reduction in the turbidity of 86 per cent. This quantity of coagulant was unusually large and was used to determine the maximum efficiencies possible under the conditions then prevailing. On October 1st, 1906, there was an average bacterial removal by the basins of 91 per cent. and 3.1 grains of alum per gallon were then used; while on July 18th, 1906, the bacterial removal was 70 per cent. and 3.0 grains per gallon were used.

In general it may be said that the bacterial efficiencies obtained by the plant are very largely effected by the basins and that the efficiency of the basins depends largely upon the length of the coagulating period, and the quantity of coagulant used. The evidence indicates that a very considerable saving in coagulant would be effected by providing a longer period of coagulation and sedimentation. This is particularly true during periods of high turbidity in the river, when larger basins and a double application of the coagulant would eliminate considerable absorption of the alum by the suspended matter, and would also cause a better preparation of the water for filtration. There would result also a decrease in the quantity of wash water required.

Filters.

Rate of Filtration. As has been stated, no difficulty has been experienced in maintaining practically constant rates of filtration at Youngstown even without automatic controllers.

Washing. The examination of July (16-20), 1906, was at the request of the superintendent, who stated that he was having trouble with formation of hard spots in the filters. As is shown in the daily records, there had been an unusually large number of bacteria in the filtered water for some time preceding the examination, and it was apparent that the poor efficiencies were due to the formation of hard spots in the filters, and consequent uneven rates of filtration. The new method of washing the filters, devised in July, 1906, was much more efficient, as a better distribution of the air was obtained. After the beds were thoroughly cleaned by the new method of washing no further trouble was experienced, and the sand in all the filters has been clean and free from hard spots at each examination. It is of interest to note that the percentage of wash water is just within the guarantee furnished for the plant. It is probable that somewhat less quantities of wash water would be required if central gutters were provided, which would permit a more rapid carrying away of the dirty wash water, and would render unnecessary the small high pressure pipes provided in the center of the filters.

As has been previously stated, considerable variation in the bacterial removal by the filters has been noted during a day's run. The best results are obtained when the least quantity of water is filtered, and the corresponding coagulating periods are greatest.

The large numbers of bacteria in the filtered water on October 1st, 1906, were due to the use of too little coagulant. Heavy rains on September 30th caused a sudden increase in the bacterial content of the raw water, requiring an increase in coagulant which was not started soon enough, and there resulted a poor efficiency by the plant. That this was temporary, however, is indicated by

the improvement in the results soon following. It is of interest to note the large number of bacteria in the mains at this time. The results on the day following indicate but 460 bacteria per c. c. in the filtered water at the plant, and 54,000 in the raw water showing a bacterial removal of 99.1 per cent. The quantity of coagulant applied on October 3d was 3.2 grains per gallon.

The average bacterial removal by the plant for the years 1906 and 1907, as indicated in the daily records was 98.8 and 99.1 per cent. respectively, and the average quantity of coagulant applied was very nearly 2.7 grains per gallon. These results, particularly those of 1907, indicate a very satisfactory operation of the plant.

The coli tests shown in the daily records were presumptive only. Two samples of raw and filtered water were tested daily and the formation of more than 15 per cent. of gas in the Smith tube was considered a positive test for coli. In 1906 the analyses indicate a possibility of 11 per cent. of the samples of filtered water containing coli, but it is well known that the positive presumptive tests are not significant, and that they indicate approximately 40 per cent. more positive tests than would be obtained with a complete differentiation. In 1907 the percentage of positive coli tests in 1 c. c. was but 4, so that at least 97 per cent. of the samples contained no coli in 1 c. c.

In December, 1907, the coli tests were extended and included the examination of 50 c. c. samples of filtered water. These were first enriched with carbolated dextrose, incubated twelve hours, and then a portion of the samples transferred to fermentation tubes containing bile. Twenty-one per cent. of these tests gave positive results in 50 c. c. while no coli were found in the 1.0 c. c. portions of the same samples.

Typhoid Investigation.

During 1906, although the filter plant was in operation, there continued to be a large number of cases of typhoid fever in Youngstown, and a thorough investigation of these cases was made by the assistant engineer of the State Board of Health in September and October of this year.* The history of 153 cases was thoroughly investigated, particularly with reference to all possible sources of infection. The results indicate that while some of the early cases may have been due to the use of filtered water, undoubtedly the majority had been caused by drinking water from polluted wells. In this connection it should be stated that during the early operation of the plant there was a popular prejudice against the use of filtered water, as it was thought that no plant, however well operated, could satisfactorily purify the water of the Mahoning River. On this account the use of wells for drinking purposes was largely continued. The evidence obtained during the typhoid investigation showed that many of these wells were polluted and should be closed. No action was taken by the local Board of Health on the recommendations of this report.

SUMMARY OF RESULTS OF SPECIAL INVESTIGATION.

In determining the potability of the Youngstown water supply there are at least three factors to be considered, namely, the total number of bacteria contained, the presence of coli, and the prevalence of water-born diseases such as typhoid fever among the water consumers.

The total number of bacteria in the filtered water in 1906 was greater than is considered desirable, but the evidence indicates that not more than 6 per cent. of all the samples tested contained coli(in 1 c. c.). During four months in the summer, however, when considerable trouble was experienced in properly washing the filters, it is of interest to note the increase in the percentage of positive

*Ref. Report of Ohio State Board of Health for 1906.

coli tests. In 1907 the tests prove the absence of coli in at least 97 per cent. of the 1.0 c. c. portions of the samples tested and 79 per cent. of the 50 c. c. portions tested in December. The total number of bacteria during 1907 has been but 200, a figure considerably less than the number in 1906.

In conclusion it should be stated that from the evidence obtained during the investigation, it is apparent that the filter plant has, as a rule, been doing very satisfactory work, and that the purification accomplished is as great as it is reasonable to expect. Although there is a constant and considerable pollution of the Mahoning River at Youngstown, the wholesomeness of the water supply is indicated by the removal of coli, by the comparatively small number of bacteria contained, and the absence of water-born diseases among the water consumers as determined during the investigation by the assistant engineer of the State Board of Health. (See Annual Report for 1906.)

Owing to the constant pollution in the river, it is necessary to use large quantities of coagulant at all times and it is apparent that much more economical results could be obtained by providing larger coagulating basins and a secondary application of the coagulant. This would reduce the quantity of coagulant necessary and also the waste water used to wash the filters.

The sudden increase in pollution of the river following local rains indicates considerable surface washing into the stream probably from the unsewered district in Youngstown above the intake. This suggests the desirability of moving the intake to a point above local pollution.

COST OF INSTALLATION.

In the following table is shown the cost of construction of the filter house, boiler house, clear well and pipe connections to the old pumping station across the river. Under the item "Engineering and Inspection" is included also the cost of laying the connection from the clear well to the high service pumping station, which connection was made by the city.

FILTER HOUSE AND CLEAR WELL		$107,171
Includes boiler house and extras.	$3,850	
MACHINERY		14,102
Pumping Machinery	$9,405	
Boilers and Stacks	4,239	
2 Feed Pumps	220	
Steam Traps	238	
VALVES AND CONNECTIONS		5,106
Pipe Connections	$2,568	
Valves and Miscellaneous	2,538	
ENGINEERING AND INSPECTION (Includes labor on river crossing)		4,733
PIPES FOR RIVER CROSSING		693
STEAM HEATING		2,850
ELECTRIC WIRING (Includes some wiring in old pumping station.)		4,073
ROOF OF CLEAR WELL		361
LUMBER FOR INTAKE		138
TOTAL COST OF CONSTRUCTION		$139,227

COST OF MAINTENANCE — 1906.

In the following table is shown the cost of maintaining the Youngstown filter plant for the year 1906. This includes the entire cost of maintenance of the purification plant, but none of the expense incurred in the operation of the old pumping station. It will be seen that the costs of labor and coagulant at the plant are high on which account the total cost of filtered water is unusually large.

LABOR			$11,700
Superintendent	$150 per mo.	$1,800	
3 Engineers	85 " "	3,060	
3 Firemen	70 " "	2,520	
3 Filter Attendants	75 " "	2,700	
1 Assistant Machinist	70 " "	840	
1 Janitor	65 " "	780	
FUEL			1,500
Total cost of coal delivered, at $1.75, is $9,321, of which the cost of the amount used at the filter plant is estimated at $1,500.			
COAGULANT, $22.05 per day			8,048
INTEREST — Interest on waterworks bonds			5,000
TOTAL COST OF MAINTENANCE			$26,248
Total number of gallons filtered during 1906			2,012,000,000
Average cost per million gallons			$13 05
Labor per million gallons		$5 82	
Fuel per million gallons		74	
Coagulant per million gallons		4 00	
Interest per million gallons		2 49	

In the following table is shown an estimated cost of filtration per million gallons when the plant is operated at its maximum capacity:

LABOR	$3 21
FUEL	74
*COAGULANT, 375 lbs. @ 0.84 cents	3 15
INTEREST	1 37
TOTAL	$8 47

NOTE — Since Jan., 1908, alum has been purchased for $16.80 per ton.

TABLE NO. 49.

Youngstown — Record of Operation.

Month.	Gals. Water Filtered.[1]	Alum.		Parts per Million.						Bacteria per C. C.		Percent Removal.	Coli in 1 C. C. P.Ct.Pos. Tests.[2]	
				River Water.				Filtered Water.						
		Gr. Per Gal.	Cost Per Mil. Gal.	Turbidity.	Color.	Alkalinity.	Chlorine.	Color.	Alkalinity.	River.	Effluent.		River.	Effluent.
1906														
April	5,266,666	2.46	$3 33	51	....	53	5.8	0	38	14,000	140	99.0	100	2.0
May	5,462,677	3.01	4 33	32	....	78	3.4	0.5	54	18,000	370	97.8	95	5.0
June	5,704,033	2.90	4 10	28	....	115	6.0	.4	102	176,000	2,200	98.7	100	2.1
July	5,719,000	2.99	4 25	67	....	111	3.7	C	84	79,000	1,000	98.6	100	16.0
August	5,727,064	2.97	4 21	103	....	71	1.7	13.0	540	63,600	720	98.7	100	27.0
September	5,658,600	2.83	4 11	60	....	91	4.4	0	70	59,000	610	99.2	98	14.0
October	5,492,400	2.82	4 06	59	....	50	1.5	4.9	33	23,000	450	98.3	100	22.0
November	5,291,400	2.66	3 83	56	....	53	2.0	1.3	34	12,000	105	99.1	96	6.0
December	5,313,600	2.66	3 82	64	57	54	2.0	1.8	29	21,000	180	99.1	100	2.0
Average	5,511,715	2.81	4 00	58	57	73	3.4	2.4	54	52,000	641	98.8	99	10.7
1907														
January	5,687,000	2.67	3.81	101	48	33	1.5	4	15	21,000	80	99.6	100	0
February	6,204,000	2.51	3 58	49	18	65	1.7	1.3	47	11,000	55	99.4	91	4
March	5,753,000	2.95	4 54	162	24	36	1.7	1.2	18	21,000	150	99.2	100	2
April	5,502,000	2.52	3 77	59	32	57	2.1	2.1	39	11,000	100	99.0	100	2
May	5,402,000	2.52	3 54	73	34	61	2.0	3.7	42	10,000	140	98.6	100	8
June	5,670,000	2.68	3 86	115	50	46	2.0	4.0	27	22,000	140	99.3	91	13
July	6,129,000	2.53	3 51	47	46	76	3.0	5	55	25,000	510	98.6	92	6
August	6,499,000	2.89	3 99	26	33	91	6.0	3	69	33,000	165	99.5	100	2
September	6,482,000	2.70	3 98	16	16	111	6.0	2	88	60,000	450	99.5	96	8
October	6,763,000	2.81	3 27	30	50	83	4.0	3.0	63	24,000	90	99.5	100	0
November	6,498,000	2.71	3 84	37	61	71	3.4	4.8	50	20,000	300	98.7	92	4
December	6,312,000	2.35	3.51	27	24	89	4.0	3	68	30,000	200	99.3	96	0[3]
Average	6,075,000	2.61	3.76	62	35	68	3.1	3	48	24,000	200	99.1	96	4

[1] Does not include wash water. [2] By fermentation in Smith tubes. [3] 21 per cent. positive tests in 50 c. c. using bile.

TABLE NO. 50.

Youngstown — Results of Analyses During Examinations.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	
	1906	A. M.								
221	7-18	8:00	Raw water	28,400	.....	.....	210[2]	120	90	.....
		M.								
226	7-18	12:00	Raw water	14,000	.....	.....	.....	.....	89	.....
		P. M.								
234	7-18	4:00	Raw water	24,000	.....	.....	140	65	89	.....
239	7-18	8:00	Raw water	32,000	.....	.....	.....	.....	.....	.....
		Md.			.....	.....	.....	.....	.....	.....
249	7-18	12:00	Raw water	11,500	.....	.....	.....	.....	.....	.....
		A. M.								
251	7-19	4:00	Raw water	15,500	.....	.....	.....	.....	.....	.....
253	7-19	8:00	Raw water	19,500	.....	.....	175	55	90	.....
264	7-19	11:30	Raw water	18,200	.....	.....	.....	.....	.....	.....

TABLE NO. 50 — Continued.

Field No.	Collected.		Source.	Bacteria Per C. C.	Colon in		Parts Per Million.			
	Date.	Hour.			1 C. C.	100 C. C.	Col.	Turb.	Alk.	
272	7-19	P. M. 4:00	Raw water	8,000	.....	.....	.....	55	94	.....
223	7-18	A. M. 10:00	Set. basin, outlet No. 1....	5,500	.....	.....	.....	.....	.....	.....
239	7-18	P. M. 2:00	Set. basin, outlet No. 2....	5,100	.....	.....	.....	.....	.....	.....
235	7-18	4:00	Set. basin, outlet No. 1....	1,500	.....	.....	.....	.....	.....	.....
255	7-19	A. M. 9:30	Set. basin, outlet No. 1....	2,300	.....	.....	.....	.....	.....	.....
256	7-19	9:30	Set. basin, outlet No. 2....	3,200	.....	.....	.....	.....	.....	.....
220	7-18	8:00	Filtered water from pump..	675	.....	.....	0	0	.....	.....
222	7-18	9:30	Filtered water from pump..	1,600	.....	.....	0	0	60	.....
224	7-18	11:00	Filtered water from pump..	400	.....	.....	.....	.....	.....	.....
225	7-18	M. 12:00	Filtered water from pump..	350	.....	.....	0	0	.....	.....
228	7-18	P. M. 2:00	Filtered water from pump..	350	.....	.....	.....	0	60	.....
232	7-18	3:00	Filtered water from pump..	375	.....	.....	.....	.....	.....	.....
236	7-18	4:15	Filtered water from pump..	475	.....	.....	0	0	.....	.....
238	7-18	6:15	Filtered water from pump..	150	.....	.....	.....	.....	.....	.....
248	7-18	8:10	Filtered water from pump..	250	.....	.....	.....	.....	.....	.....
250	7-18	Md. 12:00	Filtered water from pump..	70	.....	.....	.....	.....	.....	.....
252	7-19	A. M. 4:00	Filtered water from pump..	70	.....	.....	.....	.....	.....	.....
254	7-19	8:00	Filtered water from pump..	475	.....	.....	0	0	62	.....
257	7-19	10:00	Filtered water from pump..	190	.....	.....	.....	.....	.....	.....
268	7-19	11:00	Filtered water from pump..	80	.....	.....	.....	.....	.....	.....
271	7-19	P. M. 4:00	Filtered water from pump..	20	.....	.....	.....	0	64	.....
227	7-18	P. M. 1:15	Fountain in square.....	325	.....	.....	.....	0	.....	.....
230	7-18	2:48	Effluent No. 5 [1]	1,500	.....	.....	.....	.....	.....	.....
231	7-18	2:51	Effluent No. 5.....	375	.....	.....	.....	.....	.....	.....
233	7-18	3.19	Effluent No. 5.....	325	.....	.....	.....	.....	.....	.....
237	7-18	4:50	Effluent No. 5.....	400	.....	.....	0	0	.....	.....
240	7-18	8:00	Effluent No. 1.....	240	.....	.....	.....	.....	.....	.....
241	7-18	8:00	Effluent No. 2.....	110	.....	.....	.....	.....	.....	.....
242	7-18	8:00	Effluent No. 3.....	240	.....	.....	.....	.....	.....	.....
243	7-18	8:00	Effluent No. 4.....	275	.....	.....	.....	.....	.....	.....
244	7-18	8:00	Effluent No. 5.....	275	.....	.....	.....	.....	.....	.....
245	7-18	8:00	Effluent No. 6.....	190	.....	.....	.....	.....	.....	.....
246	7-18	8:00	Effluent No. 7.....	160	.....	.....	.....	.....	.....	.....
247	7-18	8:00	Effluent No. 8.....	180	.....	.....	.....	.....	.....	.....
258	7-19	A. M. 10:00	Effluent No. 9.....	250	.....	.....	.....	.....	.....	.....
259	7-19	10:00	Effluent No. 10.....	325	.....	.....	.....	.....	.....	.....
260	7-19	10:00	Effluent No. 11.....	220	.....	.....	.....	.....	.....	.....
261	7-19	10:00	Effluent No. 12.....	275	.....	.....	.....	.....	.....	.....
262	7-19	11:00	Filtered water in lab.....	180	.....	.....	0	0	64	.....
265	7-19	11:57	Effluent No. 8 [2]	50	.....	.....	.....	.....	.....	.....
266	7-19	12:02	Effluent No. 8.....	.....	.....	.....	.....	.....	.....	.....
267	7-19	12:17	Effluent No. 8.....	70	.....	.....	.....	.....	.....	.....
268	7-19	12:38	Effluent No. 8.....	210	.....	.....	.....	.....	.....	.....
269	7-19	1:38	Effluent No. 8.....	80	.....	.....	.....	.....	.....	.....
270	7-19	2:38	Effluent No. 8.....	20	.....	.....	.....	.....	.....	.....

[1] Filter washed and started in service at 2:40 P. M.
[2] Filter washed and started in service at 11:57 A. M.
[3] Color on unfiltered samples.
Grains of alum per gallon 7-18, 3.0; 7-19, 3.0.

TABLE NO. 50 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C. C.	Colon in 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	
	1906	A. M.								
554	10-1	11:15	Raw water	55,000	.....	.....	15	55	100	.....
		P. M.								
556	10-1	2:00	Raw water	78,000	.....	.....	.....	60	87	.....
560	10-1	6:00	Raw water	72,000	.....	.....	25	110	95	.....
562	10-1	10:00	Raw water	93,000	.....	.....	25	100	98	.....
			Average	74,500	.....	.....	22	105	95	.....
558	10-1	4:30	Set. basin, outlet No. 1.	14,000	.....	.....	.....	.....	.....	.....
559	10-1	4.30	Set. basin, outlet No. 2.	9,500	.....	.....	.....	.....	.....	.....
			Average	10,750	.....	.....	.....	.....	.....	.....
		A. M.								
553	10-1	11:15	Filt. water at pump	13,500	.....	.....	5	0	78	.....
		P. M.								
557	10-1	2:00	Filt. water at pump	3,300	.....	.....	5	0	78	.....
561	10-1	6:00	Filt. water at pump	4,600	.....	.....	5	0	69	.....
563	10-1	10:00	Filt. water at pump	2,000	.....	.....	5	0	73	.....
			Average	5,850	.....	.....	5	0	75	.....
555	10-1	2:00	Horse trough in square	11,500	.....	.....	10	0	78	.....
		A. M.								
564	10-2	2:00	Raw water	88,000	.....	.....	32	90	90	.....
566	10-2	6:00	Raw water	95,000	.....	.....	36	100	75	.....
569	10-2	10:00	Raw water	100,000	.....	.....	32	100	71	.....
		P. M.								
574	10-2	2:00	Raw water	135,000	0	0	.....	95	68	.....
578	10-2	6:00	Raw water	135,000	0	+	32	90	68	.....
580	10-2	10:00	Raw water	80,000	.....	.....	.....	80	67	.....
			Average	105,500	.....	.....	33	93	73	.....
		A. M.								
570	10-2	10:00	Ent. to set. basin [1]	3,700	.....	.....	.....	.....	30	.....
571	10-2	10:00	Water on filter No. 1.	12,500	.....	.....	.....	.....	46	.....
		P. M.								
576	10-2	3:00	Outlet of basin No. 1.	3,850	.....	.....	.....	.....	.....	.....
577	10-2	3:00	Outlet of basin No. 2.	6,600	.....	.....	.....	.....	.....	.....
			Average	5,225	.....	.....	.....	.....	.....	.....
	1906	A. M.								
565	10-2	2:00	Filt. water at pump	1,600	.....	.....	5	0	69	.....
567	10-2	6:00	Filt. water at pump	1,100	.....	.....	5	0	67	.....
572	10-2	10:00	Filt water at pump	2,500	.....	.....	25	0	54	.....
		P. M.								
575	10-2	2:00	Filt. water at pump	360	0	0	0	0	29	.....
579	10-2	6:00	Filt. water at pump	430	0	+	5	<5	26	.....
581	10-2	10:00	Filt. water at pump	420	0	0	3	<5	24	.....
			Average	1,070	.....	.....	9	<5	45	.....
		A. M.								
568	10-2	6:45	Horse trough in square	2,000	.....	.....	.....	.....	.....	.....
		P. M.								
573	10-2	1:45	Tap at Elks' Club House	2,300	0	0	15	<5	60	.....
		A. M.								
582	10-3	2:00	Raw water	80,000	.....	.....	53	75	67	.....
584	10-3	6:00	Raw water	60,000	.....	.....	60	.....	64	.....
		M.								
590	10-3	12:00	Raw water	55,000	.....	.....	40	.....	60	.....
		P. M.								
592	10-3	6:00	Raw water	46,000	.....	.....	69	.....	65	.....
		Md.								
595	10-3	12:00	Raw water	27,000	.....	.....	53	.....	61	.....
			Average	53,600	.....	.....	55	75	63	.....
		A. M.								
587	10-3	9:00	Outlet basin No. 1 [2]	4,100	.....	.....	.....	.....	.....	.....
588	10-3	9:00	Outlet basin No. 2.	4,900	.....	.....	.....	.....	.....	.....
			Average	4,500	.....	.....	.....	.....	.....	.....

[1] Increased rate of application of alum at 8:00 A. M., October 2.
[2] Decreased rate of application of alum at 7:00 A. M., October 3.
Grains of alum per gallon applied 10-1, 3.1; 10-2, 6.0; 10-3, 3.2; 10-4, 3.4.

TABLE NO. 50 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in 1 C.C.	Colon in 100 C.C.	Parts Per Million. Col.	Turb.	Alk.	
583	10-3	2:00	Filt. water at pump.....	110	0	0	3	<5	25	.....
585	10-3	6:00	Filt. water at pump.....	250	0	0	4	<5	30	.....
589	10-3	10:00	Filt. water at pump.....	340	0	0	5	0	31	.....
		P. M.								
591	10-3	2:00	Filt. water at pump.....	1,250	.....	.....	8	<5	39	.....
593	10-3	6:00	Filt. water at pump.....	350	0	0	26	<5	43	.....
594	10-3	10:00	Filt. water at pump.....	170	0	0	6	<5	38	.....
			Average	460	0	0	9	<5	34	.....
		A. M.								
586	10-3	6:30	Tap at Elks' Club House....	370	0	+	5	<5	33	.....
597	10-4	6:00	Raw water	34,000	0	+	60	.....	58	.....
	1906	A. M.								
596	10-4	2:00	Filt. water at pump.....	390	0	+	6	<5	35	.....
598	10-4	6:00	Filt. water at pump.....	420	0	0	20	<5	38	.....
			Average	405	.....	.....	13	<5	37	.....
599	10-4	6:30	Tap at Elks' Club.....	200	0	+	12	<5	39	.....
	1907	P. M.								
1063	3-12	2:00	Raw water	19,000	+	+	12	60	65	.....
1066	3-12	3:30	Raw water	17,400	.....	.....	.....	.....	.....	.....
1069	3-12	8:00	Raw water	28,000	+	+	.....	80	64	.....
1065	3-12	2:00	Set. water top No. 7.....	3,600	+	+	2	.....	42	.....
1064	3-12	2:00	Filt. water at pump.....	40	0	0	2	<5	42	.....
1067	3-12	3:30	Filt. water at pump.....	47	.....	.....	.....	.....	.....	.....
1070	3-12	8:00	Filt. water at pump.....	160	0	0	2	<5	42	.....
1068	3-12	6:13	Tap at Colonial Hotel.....	50	0	0	4	<5	43	.....
		A. M.								
1071	3-13	7:00	Raw water	41,000	+	+	12	350	32	.....
		P. M.								
1075	3-13	1:00	Raw water	46,000	0	0	8	375	20	.....
1077	3-13	3:30	Raw water	60,000	+	+	.....	375	15	.....
		A. M.								
1072	3-13	7:00	Set. water, top No. 7.....	4,000	0	0	.....	45	21	.....
1076	3-13	1:00	Set. water, top No. 7.....	3,100	0	0	.....	55	4	.....
	1907	A. M.								
1073	3-13	7:00	Filt. water at pump.....	90	0	0	2	<5	25	.....
		P. M.								
1077	3-13	1:00	Filt. water at pump.....	120	0	0	2	<5	7.5	.....
1078	3-13	3:30	Filt. water at pump.....	160	0	0	.....	<5	5	.....
		M.								
1074	3-13	12:00	Tap at Colonial Hotel.....	75	0	0	2	<5	12	.....
		P. M.								
1080	3-14	4:00	Raw water	60,000	0	+	12	375	14	.....
1081	3-14	4:00	Settled water	7,300	0	0	.....	.....	3	.....
1082	3-14	4:00	Filt. water at pump.....	950	0	0	4	<5	3	.....
1079	3-14	1:00	Tap at Colonial Hotel.....	350	0	0	2	<5	3	.....
		A. M.								
1084	3-14	7:00	Raw water	52,000	+	+	10	400	14	.....
1085	3-14	7:00	Settled water	14,500	0	0	.....	80	3	.....
1086	3-14	7:00	Filt. water at pump.....	1,300	0	0	2	< 5	3	.....
		P. M.								
1087	3-14	4:00	Filt. water at pump.....	1,350	0	0	.....	<5	3	.....
		A. M.								
1083	3-14	7:00	Tap at Colonial Hotel.....	950	0	0	2	<5	3	.....

Incrustants, samp. No. 1084 — 29; samp. No. 1085 — 35; samp. No. 1086 — 25.
For quantity of coagulant used see page 293.

TABLE NO. 50 — Continued.

Field No.	Collected. Date.	Collected. Hour.	Source.	Bacteria Per C. C.	Colon in[2] 1 C. C.	Colon in[2] 100 C. C.	Parts Per Million. Col.	Turb.	Alk.	CO_2
	1907	A. M.								
1176	4-20	7:00	Raw water	4,800	.....	.....	18	24	66	4
1178	4-20	8:00	Raw water	9,500	.....	.....	.....	.....	64	3.5
1180	4-20	9:00	Raw water	14,000	.....	.....	15	35	65	3
1183	4-20	10:00	Raw water	22,500	.....	.....	.....	30	65	4
1185	4-20	11:00	Raw water	5,300	.....	.....	15	.....	66	.....
1187	4:20	12:00	Raw water	2,200	.....	.....	.....	40	64	4
		P. M.								
1189	4-20	1:00	Raw water	2,100	.....	.....	.....	.....	66	.....
1191	4-20	2:00	Raw water	805	.....	.....	.....	.....	64	.....
1193	4:20	3:00	Raw water	3,100	.....	.....	15	45	66	4
1195	4-20	4:00	Raw water	3,300	.....	.....	15	30	65	.....
1197	4-20	5:00	Raw water	2,600	.....	.....	.....	35	66	.....
1199	4-20	6:00	Raw water	3,300	.....	.....	.....	.....	64	.....
			Average	6,200	.....	.....	16	34	64	4
		A. M.								
1177	4-20	7:00	Filtered water	360	.....	.....	2	<5	44	11
1179	4-20	8:00	Filtered water	175	.....	.....	2	<5	45	13
1182	4-20	9:00	Filtered water	230	.....	.....	2	<5	43	14
1184	4-20	10:00	Filtered water	68	.....	.....	4	<5	39	15
1186	4-20	11:00	Filtered water	44	.....	.....	4	<5	38	.....
1188	4-20	12:00	Filtered water	16	.....	.....	4	<5	39	11
		P. M.								
1190	4-20	1:00	Filtered water	9	.....	.....	4	<5	43	.....
1192	4-20	2:00	Filtered water	9	.....	.....	4	<5	44	.....
1194	4-20	3:00	Filtered water	20	.....	.....	4	<5	44	12
1196	4-20	4:00	Filtered water	42	.....	.....	4	<5	46	.....
1198	4-20	5:00	Filtered water	110	.....	.....	4	<5	47	.....
1200	4:20	6:00	Filtered water	260	.....	.....	4	<5	47	.....
			Average	112	.....	.....	4	<5	43	12
1201 to 1219	4-22	9 A.— 6 P.	Average, raw water[1]	.....	.....	.....	15	34	67	4
1202 to 1220	4-22	9 A.— 6 P.	Average filt. water	.....	.....	.....	4	<5	45	12
1221 to 1225	1907 4-23	9 A.— 5 P.	Average raw water	.....	.....	.....	15	28	68	.....
1222 to 1226	4-23	10:30 A. M. —5 P.	Average filt. water	.....	.....	.....	4	5	49	.....
		A. M.								
1227	4-24	7:00	Raw water	25,000	.....	.....	15	75	75	4
1229	4-24	8:00	Raw water	29,000	.....	.....	.....	80	75	.....
1231	4-24	9:00	Raw water	40,000	.....	.....	.....	.....	74	.....
1233	4-24	10:00	Raw water	.....	.....	.....	15	90	72	.....
1235	4-24	11:00	Raw water	.....	.....	.....	.....	95	68	.....
1237	4-20	12:00	Raw water	50,000	.....	.....	.....	.....	65	.....
		P. M.								
1239	4-24	1:00	Raw water	36,000	.....	.....	.....	90	64	.....
1241	4-24	2:00	Raw water	.....	.....	.....	20	90	64	.....
1243	4-24	3:00	Raw water	65,000	.....	.....	.....	90	63	.....
1245	4-24	4:00	Raw water	.....	.....	.....	23	90	60	.....
1247	4-24	5:00	Raw water	.....	.....	.....	25	95	57	.....
1249	4-24	6:00	Raw water	.....	.....	.....	.....	95	57	.....
			Average	42,500	.....	.....	20	89	66	.....

Note variations in efficiency of filters, corresponding to changes in period of sedimentation in basins.

[1] Bacterial counts lost on 4-22 and 4-23 due to contamination of media.
Alum applied, grains per gallon, April 20, — 2.5; April 21 — 2.6; April 22 — 2.6; April 23 — 2.6; April 24 — 2.5; April 25 — 3.2; April 26 — 3.7; April 27 — 3.7.

[2] For coli results see page 291.

TABLE NO. 50 — Concluded.

Field No.	Collected. Date.	Hour.	Source.	Bacteria Per C. C.	Colon in* 1 C. C.	100 C. C.	Parts Per Million. Col.	Turb.	Alk.	CO_2
		A. M.								
1228	4-24	7:00	Filtered water	.....	.....	.....	3	<5	55	13
1230	4-24	8:00	Filtered water	.....	.....	.....	5	<5	55	.....
1232	4-24	9:00	Filtered water	500	.....	.....	.....	<5	54	.....
1234	4-24	10:00	Filtered water	550	.....	.....	4	<5	53	.....
1236	4-24	11:00	Filtered water	750	.....	.....	4	<5	54	.....
1238	4-24	12:00	Filtered water	600	.....	.....	4	<5	54	.....
		P. M.								
1240	4-24	1:00	Filtered water	250	.....	.....	3	<5	52	.....
1242	4-24	2:00	Filtered water	140	.....	.....	4	<5	50	.....
1244	4-24	3:00	Filtered water	250	.....	.....	5	<5	47	.....
1246	4-24	4:00	Filtered water	260	.....	.....	6	<5	45	.....
1248	4-24	5:00	Filtered water	.....	.....	.....	6	<5	45	.....
1250	4-24	6:00	Filtered water	.....	.....	.....	.....	<5	48	.....
			Average	412	.....	.....	4	<5	51	.....
	1907	A. M.								
1251	4-25	8:00	Raw water	.....	.....	.....	.....	120	51	.....
1253	4-25	11:00	Raw water	32,000	.....	.....	26	100	51	.....
		P. M.								
1255	4-25	2:00	Raw water	55,000	.....	.....	26	80	55	.....
1257	4-25	5:00	Raw water	55,000	.....	.....	26	80	60	.....
			Average	47,000	.....	.....	26	95	54	.....
		A. M.								
1252	4-25	8:00	Filtered water	.....	.....	.....	6	<5	38	.....
1254	4-25	11:00	Filtered water	325	.....	.....	6	<5	29	.....
		P. M.								
1256	4-25	2:00	Filtered water	350	.....	.....	6	<5	27	.....
1258	4-25	5:00	Filtered water	1,100	.....	.....	8	<5	26	.....
			Average	600	.....	.....	6	<5	32	.....
		A. M.								
1259	4-26	8:00	Raw water	.....	.....	.....	30	175	44	.....
		A. M.								
1260	4-26	8:00	Filtered water	.....	.....	.....	8	<5	29	.....
1261	4-27	7:30	Raw water	53,000	.....	.....	35	200	25	.....
1263	4-27	8:30	Raw water	40,000	.....	.....	.....	200	25	3
1265	4-27	9:30	Raw water	36,000	.....	.....	40	200	23	.....
1267	4-27	10:30	Raw water	35,000	.....	.....	.....	200	24	.....
1269	4-27	11:30	Raw water	55,000	.....	.....	46	200	22	.....
1271	4-27	12:30	Raw water	40,000	.....	.....	.....	190	22	.....
		P. M.								
1273	4-27	1:30	Raw water	42,000	.....	.....	40	190	22	3
1275	4-27	2:30	Raw water	58,000	.....	.....	.....	190	22	.....
1277	4-27	3:30	Raw water	40,000	.....	.....	45	200	22	.....
1279	4-27	4:30	Raw water	48,000	.....	.....	40	190	22	.....
			Average	44,300	.....	.....	41	196	22	3
		P. M.								
1262	4-27	7:30	Filtered water	90	.....	.....	6	<5	6	.....
1264	4-27	8:30	Filtered water	90	.....	.....	4	<5	5	18
1266	4-27	9:30	Filtered water	110	.....	.....	4	<5	9	.....
1268	4-27	10:30	Filtered water	140	.....	.....	4	<5	9	.....
1270	4-27	11:30	Filtered water	240	.....	.....	6	<5	5	.....
	1907	P. M.								
1272	4-27	12:30	Filtered water	20	.....	.....	6	<5	4.5	.....
1274	4-27	1:30	Filtered water	65	.....	.....	6	<5	4	20
1276	4-27	2:30	Filtered water	60	.....	.....	6	<5	4	.....
1278	4-27	3:30	Filtered water	80	.....	.....	6	<5	4	.....
1280	4-27	4:30	Filtered water	95	.....	.....	4	<5	4	.....
			Average	99	.....	.....	5	<5	5.4	19

*For coli results see page 291.

SUMMARY OF INVESTIGATION OF WATER PURIFICATION PLANTS.

In the following summary is included a review of the most important features of the art of water purification as illustrated by the Ohio plants. The review embraces a description, both of the conditions as observed in Ohio, and also of the general problem of the satisfactory design and operation of purification plants. There are discussed, first, the variations in character of the raw waters; second, the three general methods of purification, natural, slow sand and mechanical filtration; and finally, the costs of installation and operation of Ohio plants. The important question of coagulants, their composition and application, is the first topic discussed under mechanical filtration.

With but four exceptions, all of the purification plants in Ohio have been installed since the year 1900, and in general it may be said that the public sentiment requiring a clean, wholesome water supply is of comparatively recent development. While in the older installations of waterworks, frequently the question of quantity alone was considered, with the modern appreciation of a clean, potable water, the question of quality is now of equal importance with that of quantity, a fact which requires the installation of purification plants in practically all cases where surface waters are now used for domestic supplies.

CHARACTER OF THE RAW WATERS.

Among the surface waters used as sources of supply, and examined during this investigation, are the following: Lake Erie; the Ohio, Mahoning, Licking, Sandusky, Grand and Little Miami Rivers; and Big Stillwater and Portage Creeks.

Of the several plants examined, three have been installed merely to improve the physical properties of the supplies as they are rarely contaminated by domestic sewage. The Grand River, used for the water supply by Geneva, drains a sparsely settled watershed, and the examinations have shown no pollution. The Elyria plant is so located that the raw water consists generally of normal, unpolluted Lake Erie water. The Dennison supply is obtained from the unpolluted Stillwater Creek. The satisfactory purification of all of these supplies requires merely the removal of suspended matter.

Some of the sources examined, while normally not dangerously polluted, show the occasional presence of domestic sewage. Among these may be mentioned Lake Erie at Conneaut, Elyria, Vermillion and Lorain; the Licking River at Newark; the Mahoning River at Warren and the Ohio River at Marietta and Pomeroy. These supplies generally are too dirty to be satisfactory for domestic use without purification, and while usually unpolluted, analyses indicate the presence of domestic sewage under certain local conditions.

Still other supplies examined have been found dangerously polluted at all times. Among these are the Ohio River at Cincinnati and Gallipolis; the Rocky River at Rocky River; the Sandusky River at Upper Sandusky; the Little Miami River at Batavia; and the Mahoning River at Youngstown. All of these streams drain well populated water-sheds, the residents of which are concentrated in municipalities discharging their sewage directly into the stream. The purification of such supplies requires the removal not only of the considerable quantities of suspended matters which the rivers generally contain, but also of disease producing bacteria.

Lake Erie Water.

Of the several plants examined, five use Lake Erie as a source of supply. In all cases it has been found that the normal lake water is comparatively soft,

contains but little dissolved color, and that a satisfactory supply for domestic use is obtained by the removal of the suspended solids. Although the lake water normally contains but little suspended matter, at times of strong winds its turbidity, particularly along the shore, is largely increased by wave-action. At each of the plants examined, with the exception of Elyria, the raw water is subject to frequent dangerous pollution from the fact that the intakes are located near the mouths of rivers carrying considerable sewage. At such times the purification required is much greater than when normal lake water is treated.

Ohio River Water.

Four plants examined use the Ohio River as a source of supply. The Ohio River drains a very large well populated territory, so that it always carries a large quantity of sewage and is generally most highly polluted during low stages. At Pomeroy, where there is no local contamination, but little pollution has been found in the river during high and normal stages as the sewage carried by the river is highly diluted, while at Gallipolis and Marietta, local conditions are such that the greatest degree of pollution is immediately after heavy rains which cause local surface washing. At Cincinnati the river is always dangerously polluted. At no time during the investigation has the Ohio River been sufficiently clear to be usable for domestic purposes, and it frequently carried very large quantities of suspended matter. During the fall the water contains also considerable dissolved color. In general, the satisfactory purification of the Ohio River water requires the removal of large quantities of silt, and frequently also of a large percentage of its bacterial content.

Licking River at Newark.

The Licking River above Newark drains a sparsely populated district on which are few communities provided with sanitary sewers. The river is fed largely by springs and during low stages it has been found of satisfactory quality for domestic use without purification. After heavy rains, which cause a considerable surface washing, the river is grossly polluted and is very dirty, so that a high degree of purification is necessary at such times.

Mahoning River at Warren and Youngstown.

The Mahoning River illustrates the well known principle of the self purification of streams. Although grossly polluted at Alliance, it is partially purified by storage in several mill ponds below that city, so that at the Warren intake the river has been found but slightly polluted under normal conditions. During low stages and immediately after periods of heavy local rains, the evidence has shown a considerable pollution of the river, a fact which would indicate that the stream carries a constant quantity of sewage, and also that there is a considerable objectionable surface washing immediately after heavy rains.

At Youngstown, the Mahoning River has been found to contain always such a large relative quantity of sewage that its purification is one of the most difficult of such problems in the state. The river receives the unpurified sewage from Warren and from several municipalities below Warren, and during both high and low stages is dangerously polluted.

Rocky, Little Miami and Sandusky Rivers.

The villages of Rocky River, Batavia and Upper Sandusky derive their supplies from the Rocky, Little Miami and Sandusky Rivers, respectively, and the

evidence obtained during the special investigation indicates a constant dangerous pollution of all of these streams.

Summary.

From the above discussion of the character of the various surface waters used for municipal supplies in Ohio, it will be seen that the problem of their purification is one that has to be determined by local conditions and for which no general rules can be formulated. The degree of purification required is an important factor in determining the cost of operation of the plant and it is manifestly unfair to require a high percentage of bacterial removal by a plant which treats an unpolluted water, and of vital importance to know when it is necessary to obtain the best bacterial efficiency possible. A knowledge of the water is necessary also to determine the most efficient and economical kind of plant by which it may be purified.

FILTRATION PROCESSES.

There are three methods in general use in Ohio for the purification of surface waters, natural, slow sand, and mechanical filtration, each of which will be discussed in turn.

NATURAL FILTRATION.

Natural filtration, when efficient and when under control, is the most desirable process of water purification, as the expense of installation is comparatively small and the cost of operation is no greater than is required without purification. There are two general types of such plants in Ohio. In the one, water is collected and stored in filter galleries or cribs and flows by gravity to a central well from which it is pumped into the distributing system. In the other, the supply is obtained from filter wells or collecting pipes which are directly connected to the pumps so that the flow is maintained both by gravity and by the suction lift of the pumps. Among the former type are included plants at Linwood Park, Springfield and Painesville, while among the latter are plants at Gallipolis, Owensboro, Ky., and an abandoned intake at Conneaut. These will be briefly reviewed in the above order.

Linwood Park.

The intake at Linwood Park comprises a filter crib on the shore of Lake Erie. It was examined during the investigation and the evidence obtained indicates that the results accomplished are very satisfactory, although the supply is obtained from ground sources and not from the lake as might be expected.

Springfield.

The waterworks at Springfield were examined by the assistant engineer of the Board during May and August, 1907. The Springfield supply is obtained from a gravel deposit near Buck Creek by collecting the sub-surface water in a central well, from which it is pumped into the distributing mains. A portion of the supply is sometimes obtained also from an open reservoir which is essentially a shallow dug well as its sides and bottom are open. Provision is made whereby water from the creek may be caused to flow into the gravel bed and by this means is insured a greater quantity of water than would be the case if only sub-surface water were used.

The evidence obtained during the examination indicates that the Springfield supply is of satisfactory quality from a sanitary standpoint. From the fact that its hardness is practically equal to that of the water in the creek, it would

appear that the supply is obtained from the creek. The plant has been generally satisfactory and it has seldom been necessary to use unfiltered creek water.

PAINESVILLE.

The water supply for Painesville is obtained by the collection of Lake Erie water in filter galleries constructed on the water line of the lake. This plant was inspected by the assistant engineer of the Board on July 22, 1907. It was then learned that the intake consisted of 2,700 feet of wooden galleries which are laid in trenches 6 feet deep. The galaries, or boxes, are constructed of 2-inch lumber and have a cross section 16 inches in width and 10 inches in height (inside dimensions). The tops and bottoms of the boxes are covered with planks, but the sides are left open and consist of galvanized iron wire screens of about ¼-inch mesh.

From the evidence obtained during the examination by the assistant engineer, it would appear that, while the purification obtained at Painesville is perhaps sufficient to produce a potable water suitable for domestic purposes, it has been impossible to obtain a sufficient quantity of water at all times. From the fact that the beach is building up at the intake, the galleries are gradually receding from the shore line and on this account their capacity gradually decreases, a fact which has made it necessary to provide new galleries from time to time. Moreover, during the winter, from December to March, the capacity of the plant is frequently very much reduced by shore ice which accumulates over the galleries. When it is found impossible to obtain a sufficient quantity of filtered water, it is necessary to augment the supply with unfiltered lake water which is frequently dangerously polluted.

In general it may be said that the use of filter galleries at Painesville has been a failure, for, although the filtered supply is fairly satisfactory in quality, the quantity obtained from the galleries is subject to considerable variation and the operation of the plant is not under control in this respect.

GALLIPOLIS.

The purification plant at Gallipolis is an example of the second type of infiltration plants in which the water is collected in pipes or wells directly without storage. The evidence obtained during the special investigation indicates that the Gallipolis water supply is of uniformly wholesome quality, and in general it may be said that this plant is one of the most satisfactory of any of the purification plants examined.

OWENSBORO, KY.*

During the special investigation there was also examined the infiltration plant at Owensboro, Ky. The intake at Owensboro consists of a series of perforated pipes laid horizontally about 4½ feet beneath the bottom of the Ohio River. These pipes are directly connected to a central pipe which in turn is connected to the suction of the pumps. The evidence indicates that the supply is obtained by the infiltration of the river water through the bottom of the river into the collecting pipes and not from ground sources. The bacterial analyses indicate a very satisfactory purification and it was learned that the supply had generally been of satisfactory quality for domestic use since the original installation of the plant.

CONNEAUT.

A similar infiltration system consisting of perforated pipe was provided for one of the original installations at Conneaut. (Page 82). This method of

Ref: Engineering Record, Sept. 28, 1907.

procuring water proved very unsatisfactory owing to the rapid clogging of the strainers and filtering material above them.

Summary.

The examination at Linwood Park indicates that a filter crib is a very satisfactory method of obtaining a water supply for small plants, but it is well known that such a method is not suitable for large installations owing to lack of control of operation and to the uncertainty of the results obtained.

While the use of infiltration methods for obtaining a filtered supply is desirable for economical reasons, the installation of such a plant is generally accompanied with uncertainties as to both the quality and quantity of the water that may be obtained. On this account there have been many failures owing to lack of experimental information before construction. It is necessary to know both the degree of purification that may be expected, and, what is of the greatest importance, to be sure that a sufficient quantity of surface water can be obtained during low stages of the stream. Infiltration plants have sometimes failed because the collecting systems were placed at so great a depth beneath the stream that, especially during low stages, the supply was obtained from ground sources and not from the surface. Such a condition, while of infrequent occurrence, may result in the use of a very unsatisfactory ground water. The use of an infiltration system by which water is obtained by underdraining the bottom of a stream requires certain natural conditions, among which may be mentioned a satisfactory grade of filtering material and a sufficient velocity in the stream to avoid the deposition of silt on the surface of the filtering material. The absence of either of these conditions soon results in unsatisfactory operation, as it is then impossible to obtain a sufficient quantity of water or one of satisfactory quality.

From the fact that favorable natural conditions are required, it is seldom practicable to use infiltration plants for purifying water, and the more common methods used are slow sand and mechanical filtration.

SLOW SAND FILTRATION.

In general it may be said that none of the Ohio waters are sufficiently clear to be purified by slow sand filters without preliminary treatment. But one such plant has been examined during the special investigation, namely, that at Fostoria. The results obtained by the Fostoria plant have not been satisfactory owing partly to the poor grade of filtering material used and to the absence of necessary controlling devices.

At Camp Perry a slow sand plant is under construction. It is thought possible to purify Lake Erie water at Camp Perry by a slow sand filter from the fact that the plant is to be used only during the summer months when the lake water is comparatively clear. Owing to the abundance of labor at Camp Perry it was not necessary to include this factor in estimating the cost of operation.

MECHANICAL FILTRATION.

The most common method of purifying Ohio waters is by mechanical filtration. Of the twenty supplies examined during the investigation, sixteen depend upon the purification of the water by mechanical filters.

The rapid development that has been accomplished in the art of purifying turbid waters is very well illustrated in Ohio, where there is at Warren one of the oldest gravity filter plants in the United States; at Lorain the first municipal filtration plant installed in the United States with a guaranteed efficiency; at Cincinnati the largest mechanical filtration plant in the world, and at Columbus,

where there is about to be placed in service the largest municipal softening plant in the world, and where the process of purification is completed by mechanical filtration.

For convenience of reference, the main features of the plants examined are shown in Table No. 55. This contains information of each plant relative to the population of the municipality, water consumption, source and date of installation of waterworks and filtration plants, kind and quantity of coagulant used, size and capacity of coagulating basins and filters, data showing rates of operation and washing of filters, and finally the total and working capacity of the clear well.

As is well known, the successful operation of mechanical filtration plants depends on the preliminary preparation of the water by means of a coagulant. In view of the importance of the subject, in the following discussion there is first reviewed the evidence obtained during the investigation relative to the chemical composition of the coagulants, their reactions with the raw waters, and the means available for their application. This review is followed by a discussion of the other main features of mechanical filtration plants, namely coagulation basins, filters, and storage between filters and high service pumps.

COAGULANTS.

There are two coagulants used in Ohio, alum and copperas, the latter requiring also lime for its precipitation. The treatment of water with copperas is of comparatively recent date, for although it was well known for many years that water could be coagulated with iron salts, no practical method for their use was developed until about the year 1900.

Alum.

This investigation has shown that there are three factors that influence the satisfactory treatment of water with alum, namely, the chemical composition of the coagulant, the turbidity and the temporary hardness of the water to be treated. As mentioned in the introduction, during several of the examinations, field experiments were made in which samples of the water were treated with measured quantities of alum, the corresponding changes in alkalinity determined (using methyl orange as an indicator) and the length of time required to give a good coagulation noted. There were two purposes in view in conducting these experiments, the determination of (1) the absorption of the alum, and (2) the actual quantity of coagulant necessary to produce a good coagulation. The results of these experiments are shown in Table No. 51.

In all of the experiments there was used the Excelsior brand of alum made by the Pennsylvania Salt Manufacturing Company of Philadelphia. By analysis this has been found to contain an average of 18.25 per cent. alumina. The theoretical reduction per grain of alum applied is approximately 8.3 parts per million, but from the results in the table it will be seen that the average reduction per grain applied as determined during the experiments, for quantities of 1, 2 and 3 grains per gallon, was 7.4 parts per million. The reductions vary from 8.5 parts per million at Batavia, when the turbidity of the water was 30 parts per million to 1.5 parts per million at Warren when the turbidity of the water was 400 parts per million.

In the last column of the table is shown approximately the number of grains of alum necessary to form a visible coagulation in the water in one hour. One of the most striking features in the table is the comparatively large quantity necessary to coagulate clear waters, as illustrated in the experiments at Batavia, Geneva and Newark. The results at Newark on February 28, 1907, are of especial in-

terest. The raw water was then very clear, and three hours after the coagulant was applied there was no visible flock even with 3 grains of alum per gallon. Clay was added to other samples of the water until the resulting turbidity was approximately 25 parts per million, and when these were subsequently treated with alum a good coagulation formed in one hour with but 2 grains per gallon. These results indicate that the coagulation of clear waters by alum is very materially assisted by the addition of clay. This fact is appreciated at Warren where clay is occasionally used to start the coagulation in the basins when the raw water is clear.

The results in the table indicate a very interesting condition with turbid waters also, as shown at Warren and Youngstown during March, 1907. The Mahoning River then had a turbidity of 400 and 375 parts per million, respectively, and the alkalinity reductions indicate a large absorption of alum, even when small quantities were applied. At both plants, although the alkalinity of the raw water was only 12 and 15 parts per million, respectively, it was possible to use 5 grains of alum per gallon without the occurrence of any undecomposed alum in the filtered water. The reductions of alkalinity averaged but 1.8 parts per million using 6 grains of alum per gallon, a fact which indicates an absorption of 78 per cent. of the alum applied. These results indicate the value of a division in the application of the coagulant and the removal by sedimentation of a part of the suspended matters in the raw water before the total necessary quantity of coagulant is applied.

The results at Upper Sandusky, Batavia and Newark are also of interest, as unusually large quantities of coagulant were occasionally necessary at these plants. An inspection of the table shows that at such times the raw water had an unusually high temporary hardness. The experiments indicate that a clear, hard water offers unusual difficulties for its proper coagulation with alum.

TABLE NO. 51.

Experimental Studies of Coagulation of Representative Raw Waters using Excelsior Brand of Alum.

Date.	Place.	Turb.	Alk.	Temp. Deg. C.	Reduction of Alk. Pts. p. Mil. Per Grain of Alum p. Gallon. Alum Applied, Gr. Per Gal. 1	2	3	4	5	6	Gr. Req.[1]
Dec. 27, 1906....	Batavia	30±	148	6.0	9.0	8.5	.....	8.0	.....	8.5	2
May 20, 1907....	Batavia	160	120	17	.....	7.0	7.7	8.2	.....	.....	1
Feb. 19, 1907....	Bucyrus	50	56	10.0	7.0	7.0	7.0	7.0	.....	.....	1
Dec. 14, 1907....	Conneaut	70	79	4.0	8.0	8.0	7.7	7.5	.....	.....	1
April 3, 1907....	Conneaut	70	74	6.0	8.0	8.0	8.3	.....	.....	.....	1
Jan. 3, 1907....	Dennison	85	70	6.5	.....	7.0	6.0	6.5	.....	.....	1
April 18, 1907....	Dennison	26	96	5.5	8.0	8.5	8.3	.....	.....	.....	1
Feb. 1, 1907....	Geneva	30±	36	6.0	.....	7.4	.....	6.6	.....	.....	2
Dec. 5, 1906....	Newark	25	196	.....	7.0	6.0	6.7	.....	.....	.....	3+
Feb. 28, 1907....	Newark	<7	191	4.0	7.0	7.0	7.3	7.8	.....	.....	4+
Nov. 20, 1906....	Pomeroy	250	41	.....	7.0	7.2	7.0	.....	.....	.....	1
May 16, 1907....	Pomeroy	120	27	14.0	8.0	8.0	8.0	8.0	.....	.....	1
March 19, 1907....	Rocky River	90	52	10.0	.....	7.0	.....	6.2	.....	6.2	1
Sept. 20, 1906....	Upper Sandusky..	65	156	.....	.....	8.0	8.0	8.0	.....	.....	3
Jan. 9, 1907....	Upper Sandusky..	140	85	3.0	.....	8.0	7.7	7.5	7.4	.....	2
Oct. 5, 1906....	Warren	50	68	.....	.....	7.0	.....	6.5	.....	.....	1
March 15, 1907....	Warren	400	12	4.0	.....	5.0	.....	2.2	.....	1.5	1
Oct. 2, 1906....	Youngstown	100	70	.....	.....	.....	7.7	.....	6.8	.....	1
March 12, 1907....	Youngstown	375	15	4.0	.....	4.5	.....	3.3	.....	2.2	1
	Average	....	.....	.....	7.6	7.1	7.5	6.6	.....	.....	....

[1]In this column is shown approximately the number of grains necessary to give a visible flock in 1 hour.

By similar experiments using both the Excelsior brand of alum and that actually used at a plant there was determined the relative time required to coagulate the water using both brands of coagulant. The Excelsior brand was taken as a standard alum and when the results indicated that the local alum required a greater time to coagulate the water than the standard brand, it was generally found by analysis of the alum that its poor reaction was due to its chemical composition. Such tests were made at all of the plants using alum, and where the results showed a poor quality of coagulant, the superintendents were so notified, and they were also advised to obtain a better product.

In Table No. 52 is shown the results of the analyses of the different alums, together with their costs and the names of the manufacturers. The analyses of the alums were made in the laboratory of the Board and in accordance with the procedure outlined by White in the Journal of The American Chemical Society, May, 1902, Vol. XXIV, Page 457.

By an inspection of the table it will be seen that samples of the different alums were received in February, 1907, and again in the fall of 1907. In February, copies of the specifications for filter alums, as given by Whipple & Longley in the Journal of Infectious Diseases, Sup. No. 3, May, 1907, were sent to the superintendents and their attention directed to the necessity for alums to contain at least 17 per cent. of alumina, of which 5 per cent. should be in excess of the amount theoretically necessary to combine with the sulphuric acid present. Although in February, 1907, four of the alums (Bucyrus, Geneva, Newark and Upper Sandusky) were found unsatisfactory, in the fall of 1907 they all exceeded the requirements of the specifications.

The average per cent. total alumina in February was 17.33 and the average ratio of basicity was 1.13, while, of the analyses made in the fall, the average total alumina was 18.12 per cent. and the average ratio of basicity was 1.18.

TABLE NO. 52.

Cost and Alumina Content of Alums.

Date of Collection 1907.	Name of Municipality.	Name and Address of Manufacturers.	Price Per 100 lbs. Delivered.	Percent Alumina. Total.	Percent Alumina. Combined with H_2SO_4	Ratio of Basicity.
February	Batavia	Jarecki Chemical Co., Cincinnati, O.	$1.00	17.62	16.26	1.08
September	Batavia	Jarecki Chemical Co., Cincinnati, O.	1.00	18.18	16.84	1.11
February	Bucyrus	General Chemical Co., Chicago, Ill.	0.90	17.05[4]	14.48	1.18
October	Bucyrus	General Chemical Co., Chicago, Ill.	0.90	18.70	14.69	1.27
February	Conneaut	Erie Chemical Co., Erie, Pa.	1.00	17.30	15.16	1.14
October	Conneaut	Erie Chemical Co., Erie, Pa.	1.00	17.63	15.93	1.11
February	Dennison	Penna. Salt Mfg. Co.,[1] Pittsburg, Pa.	1.25	17.59	14.27	1.23
February	Geneva	F. H. Kalbfhesch & Co., New York City	.....	16.48[4]	15.08	1.09
October	Geneva	Penna. Salt Mfg. Co.,[1] Philadelphia, Pa.	1.50	18.24	15.78	1.15
June	Lorain	Penna. Salt Mfg. Co.,[1] Philadelphia, Pa.	1.15	17.87	15.83	1.13
February	Newark	General Chemical Co., Chicago, Ill.[3]	0.93	16.38[4]	14.96	1.11

TABLE NO. 52 — Concluded.

Date of Collection 1907.	Name of Municipality.	Name and Address of Manufacturers.	Price Per 100 lbs. Delivered.	Percent Alumina.		Ratio of Basicity.
				Total.	Combined with H_2SO_4	
August	Newark	General Chemical Co., Chicago, Ill.[3]	1.02	17.84	14.99	1.19
February	Pomeroy	Harrison Bros. & Co., Philadelphia, Pa.	2.12	17.34	15.47	1.12
May	Pomeroy	Harrison Bros. & Co., Philadelphia, Pa.	1.12	17.31	15.66	1.10
September	Rocky River	Penna. Salt Mfg. Co.,[1] Philadelphia, Pa.	1.25	17.31	15.06	1.15
October	Rocky River	Penna. Salt Mfg. Co.,[1] Philadelphia, Pa.	1.25	17.75	15.47	1.15
February	Upper Sandusky	General Chemical Co., Buffalo, N. Y.	1.05	17.62[4]	16.50	1.06
August	Upper Sandusky	General Chemical Co., Buffalo, N. Y.	1.05	17.28	15.59	1.10
October	Upper Sandusky	Penna. Salt Mfg. Co.,[1] Philadelphia, Pa.	1.25	20.53	16.05	1.28
February	Warren	Harrison Bros. & Co., Philadelphia, Pa.	1.05	17.87	15.48	1.14
September	Warren	Harrison Bros. & Co., Philadelphia, Pa.	1.05	17.33	14.19	1.22
February	Youngstown	Penna. Salt Mfg. Co.,[2] Philadelphia, Pa.	1.05	17.87	15.48	1.14
October	Youngstown	Penna. Salt Mfg. Co.,[2] Philadelphia, Pa.	1.05	18.63	15.83	1.18

Prices shown are for delivery at plant.
[1]Natrona brand. [2]Excelsior brand. [3]Calumet brand. [4]Alums not efficient.

Owing to the importance of securing a satisfactory grade of alum, it is thought wise to include in this summary a statement of the specifications mentioned above.

"The basic sulphate of alumina shall be guaranteed to contain 17 per cent. of alumina (Al_2O_3), soluble in water, and of this amount at least 5 per cent. shall be in excess of the amount theoretically necessary to combine with the sulphuric acid present. It shall not contain more than 0.1 per cent. of matter insoluble in water and it shall be practically free of chips and debris of all kinds. It shall not contain more than 0.5 per cent. of iron (Fe_2O_3), and the iron shall be preferably in the ferrous state. The alum shall be crushed to pieces of such a size that they will pass through a ring three inches in diameter."

The results in Table No. 52 indicate that there is no difficulty in securing satisfactory alums and would seem to warrant the increase in requirements for an excess of at least 10 per cent. of alumina, that is to say that the "ratio of basicity" should be at least 1.10. These more severe requirements would seem to be justified, also, from the fact that of the four alums found experimentally to be of unsatisfactory quality, two (Bucyrus and Upper Sandusky) conformed to the above specifications.

The requirement in the specifications, that the alum shall not contain more than 0.5 per cent. iron, preferably in ferrous form, can be appreciated only by experience. Practice at Batavia, Newark and Conneaut has shown that the presence of impurities (particularly ferric iron) tends to promote the formation of sludge in the solution tanks and results in the stoppage of the solution pipes. The latter have been found to contain a hard yellow scale perhaps one-quarter inch

thick. The evidence indicates that this scale does not form in brass pipes, a fact which of itself justifies the use of brass pipes, for coagulant solutions.

During this investigation there has been a decided improvement in the quality of the alums used in Ohio, and it has been endeavored to show the waterworks officials the great importance of obtaining a good coagulation at all times and to emphasize the necessity of using a good grade of alum. While the average cost per pound has been somewhat increased, a less quantity of coagulant has been necessary and more efficient results have been obtained.

Copperas.

During the investigation attention has been directed more to the results of treatment with copperas than to the actual composition of the chemical. All of the copperas used for water purification purposes in Ohio is manufactured by The American Steel & Wire Company, and comprises two grades, sugar copperas and the ordinary commercial product ($FeSO_4 \cdot 7H_2O$). The manufacture of the sugar copperas is a secret process. It is crystallized in a vacuum so that the resulting product contains somewhat less water and more iron per pound. It is granular and the particles are of very uniform size. Sugar copperas used at Marietta costs $10 per ton and at Cincinnati, $12 per ton, a price which is somewhat increased by the fact that the copperas is shipped in 100 pound bags rather than in 200 pound bags, the usual commercial size. The cost of the ordinary commercial product is about $9 per ton. Both grades of copperas have been found to contain nearly 100 per cent of the theoretical quantity of iron.

The treatment of water with copperas is more complicated than that with alum from the fact that lime is necessary for the precipitation of the iron. The reactions that take place in the treatment of water with copperas and lime are outlined below. The copperas is first added and it reacts with the bi-carbonates in the raw water. The resulting bi-carbonate of iron is soluble, but by the addition of lime it is decomposed into ferrous hydrate $Fe(OH)_2$, which in turn is oxidized into insoluble ferric hydrate $Fe_2(OH)_6$, which forms the coagulant. The reactions are as follows:

$$FeSO_4(7H_2O) + CaH_2(CO_3)_2 = FeH_2(CO_3)_2 + CaSO_4 + (7H_2O)$$
$$FeH_2(CO_3)_2 + 2Ca(OH)_2 = Fe(OH)_2 + 2CaCO_3 + 2H_2O$$
$$2Fe(OH)_2 + H_2O + O = Fe_2(OH)_6$$

A small quantity of lime is used also to neutralize the free carbonic acid in the water as follows:

$$CO_2 + Ca(OH)_2 = CaCO_3 + H_2O.$$

The above reactions are on the assumption that just sufficient lime is used as is required to neutralize the copperas and the free CO_2. When a larger quantity of lime is applied there results a partial softening of the water as follows:

$$CaH_2(CO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O.$$

The general practice in treating water is to add such a quantity of copperas as is considered necessary and then sufficient lime to neutralize and precipitate it. Experience in Ohio plants has shown that in order to obtain satisfactory results with copperas and lime it is necessary to maintain an accurate adjustment between the two chemicals, for the use of too little lime causes a poor coagulation, while the use of too much results in the formation of "after deposits" of lime in the filters.

Experience at Marietta has shown both of the above conditions. During the early operation of the plant too much lime was used, resulting in the stoppage of the air pipes in the filters by lime incrustants. The treatment was then changed to the other extreme, and too little lime was used, resulting in a poor coagulation

in the basins, and a poor bacterial removal by the plant. During this special investigation the treatment was again changed and lime is now applied so that there results a small quantity of normal carbonates in the treated water.* Such a treatment has also been found most efficient in the other plants in Ohio, where copperas is used as a coagulant. In both of the plants at Lorain, trouble has been experienced by "after deposits" of lime.

In general it may be said that present evidence indicates that satisfactory treatment by copperas and lime requires a sufficient quantity of lime to just neutralize and precipitate the copperas, and to form about 5 parts per million of normal carbonates in the filtered water. The ratio between the quantity of lime applied to the quantity of copperas, is then very nearly 0.41, a ratio which depends upon the composition of the lime and upon the character of the raw water.

Means for Applying Coagulants.

There are two general methods of applying coagulants in Ohio plants. That in most common use consists in dissolving weighed charges of the dry chemical in storage tanks, where the solution is kept until used. It is then pumped, or flows by gravity, into the raw water and its application is varied by changing either the strength of the solution or the rate of its application. When large quantities of water are treated this method requires large storage room for the solutions and at Cincinnati is used a direct method of application of the coagulant without storage, a process similar to that developed at St. Louis. Unfortunately, the Cincinnati plant has been in operation but a little while and no information is available as to the actual results obtained, particularly with reference to the constancy of the strength of the solution.

The ideal method of applying the chemical solutions is one whereby there is maintained a constant ratio between the quantity of coagulant applied and the quantity of water pumped. It is endeavored to accomplish this result at Warren by actuating the coagulant pump by a wheel in the raw water force main, and at Pomeroy, Rocky River and Vermillion by applying the coagulant solution by a small pump directly attached to the low service pump. These methods are very satisfactory for small plants. An efficient method of application is provided in the new Lorain plant, where the coagulant solution is pumped to a head tank and then flows by gravity through an adjustable orifice.

Experience has shown that iron pipes are not satisfactory for conveying the chemical solutions. Alum solutions form deposits in iron pipes, while experience at Marietta has shown that copperas solutions both deposit in iron pipes and also tend to attack and dissolve the metal of which the pipes are composed. At the old Lorain plant as at Marietta, the copperas solution pipe (of wrought iron) clogged with yellow scale. The action of copperas solution seems to depend somewhat upon its strength and the length of time during which it is stored in the pipes. Brass pipes have proven satisfactory for both alum and copperas solutions.

Means for Applying Lime.

There are two general methods of handling lime, the one as a lime water, and the other as a milk of lime. By the former method, the solutions are best prepared in saturators as at Cincinnati. The method in more general use is to handle the lime in the form of a strong milk. Data obtained during this investigation indicate considerable variation in the strength of the solutions, particularly at times when new tanks are started in operation. These variations in solution strengths contribute to the difficulties in the use of the lime and iron process, wherein, as has been shown, an accurate adjustment of the two coagulants is required.

*Note — In the fall of 1908, the air pipes at Marietta were again so clogged with "after-deposits" that it was necessary to remove and clean them.

Effect of Coagulants on Water Treated.

The chemical changes that take place when water is coagulated with alum are well understood and consist in a conversion of part of the temporary hardness into permanent hardness. There is also an increase in the free carbonic acid (CO_2) in the treated water. The changes that take place when water is treated with copperas and lime vary somewhat with the composition of the raw water, but there is always an increase in the permanent hardness of the water due to the addition of the incrustants in the copperas. The effect of such treatment on the Ohio River water is well shown in the daily records for Marietta, where the results indicate an increase in the total hardness of the water of approximately 0.5 grain per gallon for each grain of copperas applied per gallon. When the raw water contains less than 32 parts per million of bi-carbonate alkalinity there results a slight increase in the bi-carbonates in the treated water (Marietta), and when it contains more than 32 parts per million there generally results a decrease in the bi-carbonates in the treated water (Lorain). The use of an excess of lime results in a partial softening of the water, but it is also accompanied by the formation of "after deposits" in the filters.

Alum produces a more brilliant water than copperas and also removes a larger percentage of dissolved color.

Conditions Governing Choice of a Coagulant.

There are several features which influence the choice of a coagulant, among which are included, the character of the raw water, the comparative cost of the coagulants, the means available for their application, their efficiency, and finally the availability of efficient supervision.

It is essential before choosing a coagulant to obtain information relative to the color of the raw water and also to learn which chemical is the more efficient for its coagulation. The evidence during the investigation indicates that Lake Erie water is more readily coagulated with alum than with copperas, but no further information is available relative to the comparative efficiency of the coagulants on other Ohio waters. Evidence obtained since the special investigation indicates that the dissolved oxygen content of the raw water is an important factor to be considered in the copperas and lime treatment.

The copperas in general use is a by-product, for which there is a limited demand other than for water purification purposes. It is sold at about one-half the cost of alum. In comparing the cost of treatment with the two coagulants, however, it is necessary to consider not only the first cost of the chemicals, but also the total operating expenses of the plant. More labor is sometimes required for the use of copperas, and also greater expense due to the handling of the solutions. The evidence at Lorain indicates that the conditions at that plant are such that less wash water is required with alum than with copperas. The quantity of wash water used also effects the operating expenses of the plant, particularly the cost of fuel.

In the preceding discussions it has been shown that an accurate adjustment between the copperas and lime is necessary, a fact which tends to increase the difficulties of operation with this process. At two plants, Marietta and Lorain, when proper treatment was not obtained, there resulted poor efficiencies of bacterial removal by the plant.

Summary.

A review of the evidence obtained during the investigation indicates that the results accomplished by a mechanical filter plant are very largely influenced by the efficiency of the coagulating system. The treatment by copperas and lime

offers greater difficulties than that by alum, and there are also some waters so highly colored that the use of the former is not desirable. Copperas and lime treatment also require that the plant be especially designed to suit the necessities of the process, as it is essential that the application of the chemicals be adjusted with great care. With a properly designed and operated plant it is probable that equally efficient results may be accomplished with either process. At large plants where the cost of coagulant is proportionately great, copperas is perhaps more economical than alum, while with small plants, where the cost of coagulant is proportionately small, equally economical results may be obtained with alum and with much less difficulty of operation than with copperas. It should be borne in mind, however, that economy of operation is not the ultimate end of a filter plant, but that it is always essential, particularly with polluted waters, to obtain a high bacterial efficiency, and a clear, potable effluent.

Coagulation and Sedimentation Basins.

That the importance of the work done by the coagulating basins was not appreciated by the designers of the early Ohio plants is well indicated by inspection of Table No. 55, where it will be seen that the period provided for coagulation and sedimentation of the water applied to the filters varies from 0.4 hour at Vermillion to 6.0 hours at Dennison. It is only during the special investigation that the large basin at the latter plant has been used for sedimentation following the application of the coagulant. In the plants of early design, storage of the applied water was provided merely to permit a short time for the completion of the chemical reaction of the coagulant, and little provision was made for sedimentation following coagulation. At such plants practically all of the suspended matters in the raw water are removed by the filters, and when the raw water is very turbid there results a rapid clogging of the sand, so that it is necessary to wash the filters at frequent intervals. At such times it is necessary, also, to use large quantities of coagulant. Moreover, in the smaller plants circular wooden tanks are generally provided for the coagulating basins and experience shows that there is frequently very poor displacement in such tanks so that the actual period provided for coagulation and sedimentation is much shorter than the theoretical. This has been the case at Elyria, Geneva, Newark and Vermillion, where no baffles are provided in the tanks, and frequently they accomplish practically no removal of suspended matters or bacteria. During this investigation, conditions have been improved at Elyria by the installation of a new settling basin of 24 hours capacity and at Conneaut by the installation of tanks of 4 hours capacity.

Although in the majority of Ohio plants the period of sedimentation following the application of the coagulant is too short, the fact that too much sedimentation is unsatisfactory is shown by experiences at Batavia, where the period of sedimentation is sometimes greater than 12 hours. At such times, there is not sufficient residual suspended matter in the applied water to form an efficient schmutzedecke on the filter, so that the latter removes but few of the bacteria in the applied water.

Flexibility in the period of sedimentation is accomplished at Cincinnati by providing three basins and a possible use of any one of the following periods: 0.4, 2.1, 4.3 and 4.7 hours, when the plant is working at its full capacity. Moreover, the provision of a secondary point of application of the coagulant at Cincinnati should reduce the wasteful absorption of the chemical by the suspended matters in the raw water. That this is a very important factor has been shown at Youngstown and Warren, where experience indicates that, when the raw water is very turbid, there is sometimes an absorption of over 75 per cent. of the alum applied. (See Page 310.)

Relation of Size of Coagulating Basins to Economy of Operation of Plant.

There are two factors of great importance in determining the cost of operation of a mechanical filter plant, namely, the turbidity and pollution of the raw water, and the length of storage provided in the sedimentation basins. On these two factors depend largely the quantity of coagulant necessary and the quantity of wash water used. A highly turbid water requires more coagulant and wash water, and one that is badly polluted requires a higher percentage of bacterial removal and hence a greater quantity of coagulant. A long period of sedimentation requires a greater first cost of construction, but reduces the quantity of coagulant and wash water and hence permits more economical operation. Experimental information is generally necessary to determine the most economical period of sedimentation with different waters.

In Table No. 55 is shown the great variation in the above features at the several Ohio plants. Although they are all intimately related, it is difficult to determine any exact relation between them, as there are so many other variable conditions introduced in the different plants. In general it may be said that the satisfactory preparation of water for mechanical filters requires that its turbidity be reduced to not greater than 50 parts per million, and that, if sufficient sedimentation is provided, this may always be accomplished by the use of small quantities of coagulant and wash water. Variations in the turbidity of the raw water require flexibility in the period of sedimentation following coagulation, but the maximum period that should be provided depends, not on the average, but on the maximum turbidity of the raw water. Moreover, the provision of at least two points of application of the coagulant, while requiring a greater first cost of construction, permits of much greater ease of operation and also better and more economical results.

While the period of storage provided in coagulating basins is perhaps of major importance in determining their efficiencies, their proper arrangement and construction are also essential for obtaining best results. This is well illustrated at the new Lorain plant where ample coagulating capacity is provided but comparatively poor efficiencies are accomplished by the basins. Moreover, the actual displacement obtained in basins may be much less than the theoretical and best results require a proper arrangement of inlet and outlet piping, a correct proportioning of the dimensions and frequently the use of properly placed baffles. The relative position of basins with reference to the filters requires that the coagulated water be conducted to the latter with as little agitation as possible in order not to destroy the coagulant flock or precipitate (Rocky River, Bucyrus).

Filters.

In Ohio are to be found types of mechanical filter plants representative of those installed during the early history of the art of water purification (Warren, Lorain), and also types representative of the most modern practice (Cincinnati, Columbus, Lorain, Marietta and Youngstown). In all of these plants the essential features of the filters are the same and comprise a filter box or tank, the collecting or washing system including the wash water gutters, the filtering material, and the mechanical devices provided to control the operation of the filters.

Filter Tank. Of the sixteen mechanical filter plants in operation in Ohio twelve comprise filter units consisting of circular wooden tanks varying in diameter from 8 feet (Batavia) to 17 feet (Lorain, Geneva). Mechanical agitators are provided to assist in washing these filters with but two exceptions (Geneva, Newark) and in these plants no agitation is provided. In general it may be said that the use of mechanical agitators determines the adoption of circular tanks, and that

when air or other agitation is used the more common practice is to provide rectangular tanks, generally of concrete construction. By this means there is obtained a greater economy of floor space. Evidence indicates no definite relation between the most economical size of the different filter units and their total capacity, but for large plants there is greater ease and economy both of construction and operation with large units.

Strainer or Collecting System. The strainer system in a mechanical filter performs two functions, the collection of the effluent and the distribution of the wash water, and in proportion as the last requirement is fulfilled is largely determined the success or failure of the filter. There are six general types of strainer systems in Ohio plants, as follows: a false bottom of wire screen supported above the true bottom of the filter (Warren); a modification of this form consisting of a false bottom of wood or steel into which are screwed perforated brass strainers (Batavia, Elyria, Upper Sandusky); a grid of perforated brass pipes (Bucyrus, Elyria); a grid of wrought iron pipe into which are tapped brass strainers (Conneaut, Dennison, Elyria, Lorain, Marietta, Rocky River, Vermillion, Youngstown); cast iron cups or cones, covered with perforated brass plates (Geneva, Newark); concrete channels covered with removable, perforated, brass plates (Cincinnati). Where air is used for agitation it is introduced either into the collecting pipes (Youngstown) or by a separate system of brass pipes (Lorain, Marietta). Either method accomplishes practically the same results when properly used, although they require different methods of washing the filters.

The use of wire screens, while perhaps satisfactory for small units, does not give a good distribution of the wash water in large units from the fact that there is not a sufficient loss of head at the screen to control the distribution of the wash water. On this account slight variations in the condition of the sand and its degree of cleanliness may cause an uneven distribution of the wash water. Perforated brass strainers and wrought iron manifolds are in most general use and, although somewhat expensive, have proven efficient. This is true also of perforated brass pipes. One objection to these types of strainer system is that they are not readily cleaned of obstructions, either mechanical or of organic growths (Dennison). The use of concrete channels covered by removable brass plates has proven very satisfactory at Cincinnati as their construction is economical and they are also readily inspected and cleaned. Moreover, it is possible with such construction to eliminate the dead space between the points of application of the wash water by providing concrete ridges between the strainer plates. The cast iron cones covered by perforated brass plates at Geneva and Newark have not been very successful, as the units are too large, permitting a vertical stratification of the sand over the strainer cups. Moreover, considerable trouble has been experienced at Newark from leakage of sand through the strainer cups.

Arrangement of Wash Water Troughs. One of the most common causes of the failure of filters to do efficient work has been the poor methods provided for their washing. Experience has shown that it is necessary, not only to properly introduce the wash water, but also to provide gutters of ample size and properly spaced. Failure of the washing system is frequently due to the fact that the gutters provided have too small capacity and are flooded during washing, particularly in those portions of the filter farthest from the outlet to the sewer. The operators frequently consider the entire filter washed when any portion appears to be clean, so that accumulations of dirt form in those portions of the filter which are not properly drained. Experience indicates that the distance between the gutters should not be more than 7 feet, as a greater distance requires that the wash water travel too far horizontally permitting a partial deposition of the suspended solids. In but two plants in Ohio (Cincinnati, the new Lorain plant) have the gutters proven of ample size and of proper spacing.

In the large circular tanks, the horizontal distance traveled by the wash water and the less agitation at the center frequently result in poor washing in the central portions of the filters.

An inspection of Table No. 55 indicates great variations in the rate of application of the wash water, the average time required to clean the filter, and the total percentage of wash water used. These figures indicate a lack of appreciation on the part of the designers of Ohio plants of the necessity for providing efficient washing systems, and in general it may be said that the principal cause of the poor results is the inadequate provision for removing the dirty wash water. The failure of gutters to carry sufficient water is generally due to lack of appreciation that it is necessary to provide a sufficient gravity head to produce the necessary initial velocity in the gutters. Experience indicates that the depth of section is the ruling factor in the carrying capacity of a gutter. While the maximum velocity of water in the shallow gutters generally provided in Ohio plants is about 2 feet per second, in the Cincinnati gutters, which have a maximum depth of 21 inches, the maximum velocity of flow is about 4 feet per second.

Filtering Material. An inspection of Table No. 55 shows a variation in depth of filtering material from 22 inches (Warren) to 48 inches (Dennison, Elyria, Geneva, old Lorain plant, Newark). The range in effective size of the sands used is from .31 m. m. (Cincinnati) to .78 m. m. (Warren). These figures indicate considerable divergence in practice. It is of interest to note that at Warren, the oldest plant in Ohio, is used the coarsest and also the least depth of filtering material, while at Cincinnati, the most recent plant in Ohio, the filtering material is finest.

Experience at Warren indicates poor bacterial removal by the filters immediately after washing, while at Cincinnati, where there is used a very high rate of application of the wash water, the sand in the filters is hydraulically graded and is much finer at the top than at the bottom.

In general it may be said that experience in Ohio indicates that 36 inches depth of sand is ample and that a satisfactory grade of filtering material is one having an effective size of about .35 m. m. A coarse sand causes poor bacterial efficiencies immediately after washing the filter, while a fine grade causes a high initial loss of head.

Automatic Controlling Devices. Economy of operation of filter plants requires that the filters be operated continuously at their maximum efficient rate, and that the period of time between washings be as long as possible. In order to secure these conditions it is necessary to provide efficient rate controllers and loss of head gages. Plants of early design in Ohio are without either of these appliances and their operation is not automatic but depends largely upon the judgment of the operators. While it is possible to obtain satisfactory results without automatic regulating devices, in general it may be said that there are greater possibilities of obtaining poor results where such devices are wanting. The evidence during the investigation indicates that, in the absence of automatic rate controllers, high rates of filtration frequently prevail, particularly immediately after washing, and frequently result in poor bacterial efficiencies by the filters. This is especially true when plants are operated at their maximum capacity. At several Ohio plants loss of head gages are provided but not used, as the operators are sufficiently trained to be able to determine when washing is necessary. At several plants, also, it is customary to wash the filters at regular intervals without regard to the loss of head.

The evidence indicates a difference of opinion on the part of operators in regard to the maximum loss of head that should be allowed between washings; with more frequent washing, less water is required per wash, so that the total

quantity of wash water used with different periods between washing is practically the same. Moreover, there is no great difference in the bacterial purification accomplished. This latter fact is not true when large heads are available on the filters for if such filters are not washed sufficiently often, poor bacterial results may be obtained by the breaking of the schmutzedecke near the end of a run between washings. Under such conditions, poor results are generally indicated by an increase in the turbidity of the filtered water (Geneva, Newark, Upper Sandusky). Greater economy of pumping and better bacterial purification would result in such plants if less difference in elevation were provided between the water in the filters and in the clear well.

With large plants economy of labor necessary for operation requires that auxiliary power be provided to operate the regulating valves, and also that this power be applied from a central point of control. This is accomplished either by the use of hydraulic valves operated from a stand (new Lorain plant, Youngstown) or by electrically operated valves the motors of which are controlled from a central switch-board (Cincinnati). Where such devices are provided the labor cost of operation is small as is well shown at Cincinnati, where a single attendant may easily operate the filter house, the capacity of which is 112 million gallons per day.

Clear Well.

The importance of providing sufficient storage between the filters and the high service pumps has not been generally recognized by the designers of Ohio plants. Table No. 55 shows both the total storage period provided in the clear wells at the various plants, and also that actually available. An inspection of this table indicates a variation in the total storage provided of from 0.2 hour (Conneaut) to 29 hours (Batavia). In several plants the outlets of the clear wells are the suctions of the high service pumps, and are so placed that the storage actually available is considerably less than the total storage provided (Bucyrus, Conneaut, Elyria, Lorain, Newark, Warren). In twelve out of the sixteen mechanical filter plants examined, the available storage is less than two hours, and in ten is less than one hour.

The clear wells serve as equalizers and also provide storage during such times as filters are necessarily out of service for washing or other reasons. When this storage is small it is necessary either to operate some of the filters at high rates during the period of washing, or else to slow down the high service pumps. The former procedure generally results in poor efficiencies of bacterial removal, while it is not possible in all cases to resort to the second procedure, particularly when no distributing reservoir is provided. If sufficient filtering area is provided, however, an extra filter may be thrown in service when needed (Elyria).

At several plants the water used for washing the filters is pumped from the clear well so that during washing, not only is the quantity of water filtered decreased by the fact that some filters are out of service, but the draft on the clear well is increased at such times by the wash water pumps. In such plants the quantity of water used in washing is also a factor to be considered in estimating the necessary capacity of the clear wells.

On account of the difficulties of maintaining the filters and high service pump at the same rate at Conneaut, there has resulted at times a considerable waste of filtered water as it is the custom to run the filters faster than the high service pump. At the old Lorain plant, where no distributing reservoir is provided, it was necessary to maintain at least 5 feet of water in the clear well for fire protection, a fact which materially reduced the available capacity of the well. On account of the small storage provided in the clear well at this plant, it was fre-

quently impossible to wash the filters when efficient results required it. The fact that the average quantity of water pumped may be exceeded by 25 or 33 per cent. during several hours of a day, also necessitates greater storage in plants where no distributing reservoir is provided.

In general it may be said that considerable trouble is experienced in operating several Ohio plants from the fact that the clear wells have not sufficient capacity. Poor bacterial removals are occasionally obtained, and, moreover, constant attention is required by the operators in watching the pumps and filters in order to operate them at the same rate and to avoid "racing" of the high service pumps or waste of filtered water. The evidence indicates that the storage provided in clear wells should in no case be less than two hours and should be of at least double that capacity when distribution reservoirs are not provided.

Pressure Filters.

The first form of mechanical filter was of the pressure type of which class is the Pomeroy plant. From the fact that it was generally thought unnecessary to use a coagulant with pressure filters and also that a clear well is unnecessary, these filters were frequently used where a high degree of purification was not required.

The evidence obtained during the examinations of the Pomeroy plant indicates that the purification obtained is variable and frequently not sufficient to produce a potable water. Moreover, the operation of the filter is not economical from the fact that it is necessary to use large quantities of wash water. Not only are the results obtained frequently unsatisfactory, but from the fact that the filtered water is out of sight, the production of imperfectly filtered water is not detected by the operator. In general it may be said that the pressure filter at Pomeroy accomplishes a partial clarification of the supply, but does not give a consistently high bacterial removal. The evidence indicates that a regular application of a coagulant is necessary and is a most important factor in determining the percentage bacterial removal accomplished.

FEATURES OF CONSTRUCTION AND OPERATION IN RELATION TO EFFICIENCY AND ECONOMY.

In the preceding discussion there has been shown in a general way how the design and arrangement of the essential parts of the filter plants have influenced the results accomplished. It is thought desirable to state briefly the specific reasons why many plants have occasionally produced poor results.

The evidence at Batavia indicates a constantly polluted raw water and the results obtained by the plant are generally unsatisfactory, due principally to lack of appreciation on the part of the operators of the care necessary to obtain satisfactory results. Although improvements have been advised during the investigation, no results have been accomplished on account of the indifference of the officials in charge. At Bucyrus, the means for introducing the coagulant are inefficient and have not been remedied during the investigation. At Conneaut, inefficient results were obtained by the plant during the early part of 1906 on account of inexperience in proper methods of operation and also on account of inadequate coagulating facilities. Both of these conditions have been remedied in 1907. At Dennison, considerable expense was incurred and difficulty of operation resulted from growths in the strainer system. At Elyria the inadequate means provided for washing the two new concrete filters resulted in serious clogging of the sand and poor bacterial removals. At Geneva, similar conditions resulted from the fact that no agitation is provided to assist in wash-

ing. Poor results were accomplished by the old Lorain plant in 1907 from the fact that its capacity was largely exceeded and also that the means for applying the coagulants were not efficient. The new Lorain plant was operated for several months when the wash water pump provided had not sufficient capacity to satisfactorily clean the filters. Poor results obtained for some time at Marietta from gradual accumulations in the filter beds due to inefficient washing. This condition was remedied by a change in the method of washing. At both of the Lorain plants and also the Marietta plant, the improper use of coagulants has resulted in accumulations of "after deposits" in the filters and at Marietta in poor efficiencies by the coagulating basins. Considerable trouble was experienced by the leakage of sand through the strainer cups at Newark. This condition has been remedied during the investigation. At Pomeroy the means for applying coagulant have been very much improved and more satisfactory results obtained. The cost of operation has been much greater than necessary at Pomeroy from lack of repairs in the settling basin, and more economical and efficient results would doubtless obtain, also, if the point of application of the coagulant were changed as suggested during the investigation. At Rocky River, the means for introducing the coagulant have been very much improved and better results have subsequently been obtained by the plant. At Upper Sandusky poor bacterial removals were accomplished by the filters during the first part of the investigation, due to inadequate means provided to apply the coagulant. More economical operation could be obtained at Vermillion by changing the inlet and outlet piping in the receiving well. At Warren, the high rates of filtration necessary immediately after washing the filters, together with the large size and small depth of the filtering material frequently cause temporarily poor bacterial efficiencies. Trouble from inefficient washing was experienced at Youngstown in the summer of 1906, and was remedied by an improved method of washing.

From the above discussion it will be seen that at all of the Ohio plants difficulties of operation have been encountered, due either to poor construction or to lack of experience on the part of the operators. It is apparent that the mere provision of a water purification plant does not insure a potable supply, but that like any other delicate machine, a filter plant requires competent management and supervision. In but two cases have the poor bacterial efficiencies obtained been due to continued carelessness or indifference on the part of the officials in charge. At several plants the purification accomplished has been temporarily unsatisfactory on account of inefficient methods of operation, and when the cause of the trouble has been learned and removed, the efficiencies obtained have been immediately improved.

COST OF INSTALLATION OF WATER PURIFICATION PLANTS IN OHIO.

The cost of installing the Ohio water purification plants, where such information is available, is shown in Table No. 53. The total costs shown include the expense of providing purification works over and above that which would be incurred if no purification were accomplished and comprise the costs of the low service pumps; of the settling basins, where such are provided; of the filters and buildings; of the apparatus for handling the coagulant; of the coagulating basins; and of the clear wells. The cost of the boilers, boiler and pump houses and high service pumps are not included. In the third column of the table is shown the cost per million gallons filter capacity. In the fourth and fifth columns are shown, respectively, the total populations and the costs per capita based on these populations. In the last column is shown the per capita cost based on the maximum population that can be served by the plants. This figure is obtained by dividing the per capita cost by the ratio of the ultimate capacity of the plant to

the present consumption, a ratio shown in the next to the last column. The ultimate cost per capita is thus based on the assumption that the per capita consumption will be the same when the plant is operated at its maximum capacity, as it is at the present time. The ultimate cost per capita (omitting Cincinnati, Gallipolis, Pomeroy) ranges from $5.40 at Dennison, where a large settling basin is provided, to $0.51 at Vermillion, where there is very little storage for sedimentation and coagulation of the applied water. The average ultimate cost per capita is $1.44.

The cost per million gallons of filter capacity varies both with the size of the plants and the materials of construction. The smaller plants are more expensive, as the fixed charges are proportionately greater. Wooden construction is cheaper than concrete, but is less durable.

Of the three concrete plants at Lorain, Marietta and Youngstown, respectively, the ultimate per capita cost based on the population that can eventually be served by the plants ranges from $1.28 (Youngstown) to $1.55 (Marietta) and averages $1.42. The average cost per million gallons capacity of these plants ranges from $10,000 (Marietta) to $13,000 (Youngstown) and averages $11,700.

The ultimate cost per capita of the filter plants of wooden construction ranges from $0.51 (Vermillion) to $5.40 (Dennison) and averages $1.48. The cost per million gallons filter capacity ranges from $7,900 (Vermillion) to $26,000 (Dennison) and averages $13,400, a figure which is comparatively high on account of the relatively small size of the plants where wooden construction is used.

In comparing costs of installation it is necessary to consider also cost of maintenance, as a greater first cost frequently permits of much more economical operation and less depreciation.

TABLE NO. 53.

COST OF WATER PURIFICATION PLANTS IN OHIO.

Name of Municipality.	Approximate Total Cost of Purification Works.[1]	Cost per Mil. Gals. of Filter Capacity.[2]	Population.	Cost per Capita.	Ratio of Ult. Cap. to Consump.	Ult. Cost per Capita.
Cincinnati	$5,580,965	$49,830	370,000	$15 10	2.6	$5 80
Dennison	52,000	26,000	9,700	5 40	1.0	5 40
Elyria	43,000	10,000	18,000	2 40	1.9	1 26
Gallipolis	5,400	3,700	5,500	1 00	3.6	0 28
Geneva	8,000	13,000	2,500	3 20	2.5	1 28
Lorain (Old plant)	31,000	8,000	30,000	1 00	1.2	0 83
Lorain (New plant)	85,000	12,000	32,000	2 70	1.9	1 42
Marietta	48,000	10,000	15,500	3 10	2.0	1 55
Pomeroy	11,000	26,000	8,600	1 28	1.6	0 80
Rocky River	7,000	14,000	1,300	5 40	10.0	0 54
Upper Sandusky	10,000	15,000	4,500	2 20	2.5	0 88
Vermillion	3,500	7,900	1,250	2 80	5.5	0 51
Warren	18,300	13,000	12,000	1 50	1.7	0 88
Youngstown	139,000	13,000	60,000	2 30	1.8	1 28
Average						$1 44[3]

(1) Includes low service pumps, settling basins, filters and buildings, coagulant devices, coagulating basins and clear well.

(2) Based on rate of 125 million gallons per acre per day.

(3) Does not include Cincinnati, Gallipolis, Pomeroy.

COST OF OPERATING WATER PURIFICATION PLANTS IN OHIO.

In Table No. 54 are shown the cost of operating the waterworks stations, the cost of operating the purification devices, and finally the cost of operating the purification works, per million gallons. This latter figure represents the increased cost of operation due to the purification of the supply over and above the operating expenses that would be incurred without purification. As in Table No. 53 which shows the costs of installation of the plants, great accuracy is not claimed in the these figures, but they are of considerable value for comparative purposes and are as nearly exact as it was possible to obtain. The operating expenses are shown under four heads, labor, fuel, coagulant and miscellaneous, the latter containing all expenses other than are comprised in the first three items.

An inspection of the table indicates a range in total cost of operation from $11.18 (Marietta) to $56 (Rocky River). The high cost at the latter plant is due to its small size and to the fact that it is operated at but short periods with relatively high fixed charges. The low cost at Marietta is due largely to the use of comparatively cheap fuel.

The figures showing the cost of purification per million gallons are of considerable interest and range from $2.55 (Elyria) to $12.10 (Warren). The unusually low cost at Elyria is due partly to the low labor and coagulant cost, and it should be noted that the raw water at Elyria is seldom polluted, and that but a small quantity of coagulant is necessary to produce a satisfactory supply. The low fuel charges at Elyria are due to the excellent efficiency of the pumps and to the careful management of the plant. The high cost at Warren is due to the comparatively large cost of each of the different items, particularly fuel. The cost of purifying a million gallons at Youngstown, $10.67, is unusually large, and is due to the high labor charges and to the necessity for using large quantities of coagulant. The Mahoning River at Youngstown is one of the most polluted of the Ohio rivers used as water supplies and requires large quantities of coagulant for its purification. The unusually high miscellaneous charges at the new Lorain plant result from the fact that the plant is new and has required extra labor for its tuning up; also for repairing the filter beds due to poor washing and improper use of coagulants. Doubtless part of this miscellaneous charge should properly be added to coagulant.

The average increased cost of operation per million gallons (irrespective of interest charges) due to purification of the supply is $6.13, and varies with the character of the raw water, the expense of labor, the kind and cost of fuel used for pumping, and the quantity of coagulant required. The net cost of fuel and coagulant both vary largely with the design and arrangement of the purification plant. Labor charges are constant and for comparative purposes should be reduced to the cost per million gallons when the plant is operated at its maximum capacity.

TABLE NO. 54.

Cost of Operating Water Purification Plants.

Municipality.	Ratio of Ultimate Capacity to Consumption.	Tot. Expenses at Waterworks Sta.[1]					Cost Per Operating Million Gallons.	Cost of Operating Purification Works.					Cost of Purification Per Million Gallons.					Remarks.
		Labor.	Fuel.	Coag.	Misc.	Total.		Labor.	Fuel.[2]	Coag.	Misc.	Total.	Labor.	Fuel.[2]	Coag.	Misc.	Total.	
Dennison	1.0	$2,580	$4,000	$1,750	$200±	$8,530	12.04	$300±	$1,333±	$1,750	$100±	$3,483	0.42	1.88	2.47	0.14	4.92	
Elyria	1.9	6,516	2,700	656	619	10,491	13.00	400±	900±	656	100±	2,056	0.50	1.12	0.81	0.12	2.55	
Gallipolis	3.6	1,710	995	0	250	2,955	31.22	.....	.....	.....	.....	0	.....	.....	.....	.....	0	Infiltration plant.
Geneva	2.5	840	222	425	.....	1,487	16.30	0	74	425	0	499	0	0.81	4.66	0	5.47	Use water power.
Lorain (old plant)	1.2	7,598	4,610	2,837	2,639	17,684	15.20	3,480±	1,500±	2,837	325±	3,142	2.99	1.29	2.43	0.28	6.99	For 1906.
Lorain (new plant)	1.9	.....	.....	.....	.....	.....	.....	3,480	1,888	2,921	2,062	10,351	2.44	1.33	2.05	1.45	7.26	For 1907.
Marietta	2.0	4,260	3,617	1,752	223	9,852	11.18	1,800	1,200±	1,752	100±	4,852	2.05	1.36	1.99	0.11	5.52	Fuel — Natural gas.
Newark	0.9	3,700±	6,967	791	300±	11,758	15.24	300±	2,322±	791	50±	3,463	0.39	3.01	1.03	0.06	4.48	Use some ground water.
Pomeroy	1.6	1,980	868	56	200±	2,504	26.40	0	289±	56	.....	345	0	3.04	0.59	.....	3.63	Pressure filter.
Rocky River	10.0	780	216	24	.....	1,020	56.00	0	72±	24	.....	96	0	3.94	1.32	.....	5.26	
Up. Sandusky	2.5	960	360	360	200±	1,680	17.70	0	120±	360	25±	505	0	1.26	3.79	0.26	5.32	Fuel — Natural gas.
Vermillion	5.5	900	331	33	.....	1,264	43.70	0	110±	33	25±	168	0	3.79	1.14	0.86	5.80	
Warren	1.7	.....	.....	.....	.....	.....	.....	770	1,175	1,123	481	3,549	2.61	4.01	3.84	1.64	12.10	
Youngstown	1.8	.....	.....	.....	.....	.....	.....	11,700	1,500±	8,048	200±	21,448	5.83	0.75	4.00	0.10	10.67	

[1] Does not include interest, taxes, nor maintenance of distribution systems.
[2] Assumed 1/3 of total where not known.

TABLE NO. 55.—WATER PURIFICATION PLANTS IN OHIO.

Name of Municipality.	Population.	Average Daily Consumption (Gallons.)	Date of Installation. Water Works.	Date of Installation. Filter Plant.	Source of Supply.	Coagulant Used. Kind.	Coagulant Used. Aver. Quant. Gr. P. Gal.	Coagulating Basins. No.	Coagulating Basins. Total Capacity. Gallons.	Coagulating Basins. Total Capacity. Hours.[1]	Coagulating Basins. Vel. Ft. P. Min.	No.	Total Area (Acre.)
Batavia	1,100	40,000	1900	1930	Little Miami R.	Alum	2.5	2	60,000	20.	....	1	.00116
Bucyrus	6,600	625,000	1883	1905	Sandusky R.	Alum	2.0	1	46,500	1.1	....	2	.00758
Cincinnati	370,000	42,000,000	1820	1907	Ohio R.	Copperas and lime.	....	3	22,000,000	4.7	1.3	28	.090
Conneaut	9,000	1,121,000	1889	1900	Lake Erie	Alum	2.1	4	46,000	0.7	....	3	.0123
Dennison	9,700	1,941,000	1888	1900	Big Stillwater Creek	Alum	1.2	5	506,000	6.1	0.4	4	.0162
Elyria	18,000	2,211,000	1879	1903	Lake Erie	Copperas and Lime	0.75 0.33	2	159,000	0.9	....	7	.0343
Fostoria	10,000	780,000	1891	1906	Portage Cr.	None	....	....	....	....	....	2	0.52
Gallipolis	5,500	400,000±	1894	1894	Ohio R.	None	....	....	....	....	....	4	.00116
Geneva	2,500	250,000	1902	1912	Grand R.	Alum	3.0	1	52,800	2.0	....	1	.0050
Lorain (old plant)	30,000	3,190,000	1884	1897	Lake Erie	Copperas and Lime	2.5 1.0	6	60,000	0.4	....	6	.0312
Lorain (new plant)	32,000	3,910,000	....	1907	Lake Erie	Copperas and Lime	1.9 1.0	2	580,000	1.8	0.8	6	.0612
Marietta	15,500	2,270,000	1890	1901	Ohio R.	Copperas and Lime	2.2 0.77	2	440,000	2.3	0.5	8	.0368
Newark	18,000	2,200,000	1880	1901	Licking R.	Alum	0.8	1	122,000	1.4	....	4	.0162
Pomeroy	8,600	260,000	1899	1899	Ohio R.	Alum	1.6	1	[2]235,000	13.4	....	1	.0033
Rocky River	1,300	50,000	1906	1906	Rocky R.	Alum	2.0	1	50,000	2.4	....	1	.0041
Up. Sandusky	4,500	260,000	1889	1905	Sandusky R.	Alum	2.7	2	26,000	1.0	....	2	.00519
Vermillion	1,250	79,400	1904	1904	Lake Erie	Copperas and Lime	1.33 0.63	1	3,000	0.2	....	1	.00353
Warren	12,000	858,000	1887	1895	Mahoning R.	Alum	2.4	1	78,000	1.3	1.2	6	.0116
Youngstown	60,000	6,075,000	1872	1905	Mahoning R.	Alum	2.70	2	1,100,000	2.4	0.8	12	.0879

[1]Based on ultimate capacity of filters. [2]At 3,000,000 gals. per acre per day.

TABLE NO. 55.—WATER PURIFICATION PLANTS IN OHIO.

Nominal Capacity (at 125 M. G. P. A. P. D.)	Materials of Const.	Filters. Filtering Material. Depth (In.)	Eff. Size. M.M.	Unif. Coef.	Aver. Rate of Filt. M. G. P. A. P. D.	Washing. Rate, Vert. In. Per Min.	Vert Feet P. Wash.	Time Bet. Wash. Hrs.	Percent Wash. Water.	Aver. Turb. Raw Water (Pts. Per Mil.)	Clear Well. Tot. Capacity Gallons.	Tot. Capacity Hours.[1]	Working Cap. Gallons.	Working Cap. Hours.[1]	Remarks.
145,000	Wood	42	.46	1.3	160	14	9.3	24	7.8	75±	174,000	29	174,000	29	Basins used on Fill and Draw Plan.
948,000	Wood	36	.42	1.6	82	10	7.5	12	6.0	75±	217,000	5.5	102,000	2.6	Impound'g reservoirs provided also.
112,000,000	Concrete	36	.31	1.6	125	25	4.2	14	3.0±	350±	19,000,000	4.1	19,000,000	4.1	Settling basins also.
1,400,000	Wood	42	.47	1.5	95	6	10.0	10	10.2	40	12,600	0.22	6,900	0.12	New coagulating basins provided in 1907.
2,000,000	Wood	48	.48	1.3	120	12	20.0	18	8.9	320	54,000	0.65	48,000	0.58	
4,280,000	Wood and concrete	48	.48	1.5	135 and 75	10	12.2	8	8.4	100±	174,000	1.0	87,000	0.5	New coagulating basin provided in 1907.
[2]1,560,000	Concrete	36	.22	5.9	1.4	....	....	....	.....	80±	450,000	7.0	380,000	5.8	Slow sand filters. Impounding reservoirs.
1,440,000	Cast Iron.....	156	....	...	20[4]	....	....	....	.....	350±	.....	.....	.....	.....	Infiltration plant.
625,000	Wood	48	.53	1.4	120	6	12.0	5	16.	100±	40,000	1.5	30,000	1.1	No agitation in filters.
3,900,000	Wood	48	.61	1.3	104	13	9.7	12	6.2	70	225,000	1.4	100,000	0.6	Abandoned Apr., 1907.
7,650,000	Concrete	36	.44	1.4	100	12	8.0	....	8.3	135	580,000	1.8	290,000	0.9	
4,600,000	Concrete	36	.46	1.4	80	11	13.7	24	7.4	400	200,000	1.0	150,000	0.8	
2,010,000	Wood	48	.55	1.3	125	12	8.0	12	8.2	50±	33,000	0.4	16,500	0.2	No agitation in filters. Leakage of ground water.
420,000	Wrought iron...	48	.35	1.5	145	....	....	4	26.	400±	None	0	.....	.....	Pressure filter.
500,000	Wood	30	.36	1.5	Var.	9	7.5	....	19.	100±	13,500	0.6	9,700	0.5	Sup. to be taken from Lake Erie.
650,000	Wood	48	.49	1.5	95	5	4.4	5	4.2	200	147,000	5.4	120,000	4.4	Leakage of ground water into clear well.
440,000	Wood	32	.57	1.8	85	7	6.0	9±	13.0	90	11,000	0.6	9,000	0.5	
1,450,000	Wood	22	.78	1.3	75	7.8	4.5	12	4.5	90	39,000	0.6	24,700	0.4	
10,970,000	Concrete	36	.40	1.3	100	10	7.0	16	5.0	60	665,000	1.5	166,000	0.4	

[2]Settling Basin. [4]Gallons per sq. ft.

CONCLUSION.

In the preceding summary has been shown the complexity of the subject of water purification due to variations in the character of the surface waters used as sources of supplies, and to the diversity of local conditions and of available means by which purification may be accomplished. The investigation indicates that for the purification of all supplies there are four conditions necessary in order to secure the most economical and efficient results, namely, a knowledge of the raw water, the satisfactory design of purification works, their proper construction, and finally, their efficient management and operation.

Analytical evidence relative to the character of the surface waters in Ohio is best obtained by a central authority, such as the State Board of Health. Since 1893 this Board has been authorized to approve or reject all proposed methods of purification, but has not been able to enforce the construction of such plants as outlined in the plans approved. By recent legislation in 1908, the Board is authorized to examine all purification plants and to see that they are properly constructed and are operated in such a manner as to give efficient results. The investigation indicates the necessity for such a central control, for the mere provision of a purification plant does not assure a potable water, and may induce a false sense of security on the part of the consumer.

There is shown also to be a very close relation between the problem of water purification and the protection of streams from pollution by municipal wastes. The degree of bacterial purification that can reasonably be accomplished by a water purification plant is limited, so that it is necessary to eliminate from the raw water all pollution practicable, even where a purification plant is provided. It is also necessary to proportion justly the work that shall be accomplished by the water purification plants and by the sewage purification plants on the watersheds of streams used as supplies.

During the investigation there has been developed a decided improvement in the general quality of the filtered water supplies, due largely to a better understanding on the part of the officials as to the proper methods of operating the purification plants. The opportunity for personal interview afforded by the investigation has resulted in obtaining a hearty co-operation of the waterworks officials, who have generally welcomed information in regard to the results accomplished, and also recommendations whereby their plants could be improved. To this fact is largely due what success has been obtained by the Board in its investigation.

A review of the discussion of the costs of installation and operation indicates that the per capita cost entailed is small, and in general it may be said that the installation of a water purification plant has usually been followed by such an improvement in the health of the community, that the satisfaction of having a clear, potable water supply has more than repaid the small expense with which it is obtained.

Report on Examination of the Water Softening Plant at Oberlin.

BY

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Oberlin Watersoftening Plant. — Reservoir and Settling Basins.

WATER SOFTENING AT OBERLIN.

The following report discusses in detail the operation of the Oberlin water softening plant, as shown by examinations made during the special investigation of the State Board of Health as to the operation of the water purification plants in Ohio. The discussion is preceded by a brief outline of the present status of the art of water softening.

PRESENT STATUS OF WATER SOFTENING.

The art of water softening dates back to the year 1766 when Cavendish discovered that the addition of lime to natural water causes a deposition of the carbonates of lime and magnesium. Further interest in the matter was awakened in 1841 when Doctor Thomas Clark of Aberdeen patented a method for water softening with lime on a fairly large scale. Progress in water softening was somewhat slow, especially upon a scale corresponding to municipal needs, although there were built numerous small plants for railroad and manufacturing use.

One of the first municipal plants is that built at Southhampton, England, in 1888. This was one of the first continuous softening plants on a large scale. The first municipal plant in the United States was that at Oberlin, Ohio, installed in December, 1903. At that time, however, there was a plant in operation at Winnipeg, Manitoba.

Quite recently considerable advance has been made in municipal water softening and at Columbus, Ohio, there is at present under construction a plant which has a total capacity of 30,000,000 gallons, and will be the largest water softening project in the world. A smaller plant on a continuous basis is now under construction at McKeesport, Pennsylvania. While the number of water softening undertakings is quite small, particularly in the United States, yet there are numerous railway water softening plants in successful operation, especially on the western railroads where a sufficient supply of soft water is difficult to obtain without treatment for the removal of hardness.

HISTORICAL REVIEW OF OBERLIN WATER SUPPLY.

The village of Oberlin is a college town, the seat of Oberlin College, in Lorain County, in the north central part of the state. Plum Creek, a small intermittent stream tributary to the Black River, passes through the village. The village is essentially residential in character with a population of about 5,200 in the winter inclusive of 900 students; in the summer, about 4,300. The public water supply installed in 1887 is derived from the east branch of the Vermillion River near Kipton, about 5½ miles distant from Oberlin. The watershed above the intake is about 25 square miles in area and is rather flat swampy country sparsely settled and devoted almost entirely to agricultural pursuits. The soil is a glacial till which contains many limestone pebbles. There are no cities on the watershed and the population is only about 43 persons per square mile. The supply piped to Oberlin is stored in a large reservoir from which it was originally pumped to the village without further treatment.

Pumping Machinery and Power Plant.

The pumping plant comprises two, 1,000,000 gallon Deane pumps. Neither revolution counters nor pressure regulators are provided. The pumps are direct connected to the mains through a 12-inch force main used in case of fire. The pump suction is 10 inches in size, 75 feet in length and the ordinary lift is 8 feet. Ordinarily water is pumped to the standpipe, a distance of about 200 feet, through a force main 8 inches in size. The top of the standpipe is about 75 feet above the ground and under ordinary conditions there is maintained in the mains a pressure from 20 to 30 pounds per square inch. In case of fires the pressure is increased to from 75 to 100 pounds and the standpipe is cut off.

A boiler feed pump is in use and in addition there is a small auxiliary pump, for both of which steam is furnished by two horizontal tubular boilers of 80 H. P. The pumps and boilers are contained in a substantial brick building.

Standpipe.

The softened and settled water from the pump well is raised to the standpipe which is a steel tank 18 feet in diameter and 35 feet high resting on a stone structure 40 feet high. Water from the standpipe is piped directly to the pressure filters which are directly beneath and are inclosed by the stone base of the standpipe.

Filters.

To remove the precipitates remaining in the softened and settled water, there are two riveted steel filters of the pressure type, 7 feet in diameter and each with an area of 38.48 square feet. The filters have a combined nominal capacity of 220,000 gallons in 24 hours. The original filtering material was a coarse Cape May silica sand. In the spring of 1906, this was replaced by lake sand and after six months' use the lake sand was also removed and as now in use was replaced with about 24 inches of Cape May sand. This sand cost $4.05 per ton f. o. b. Oberlin, or $5.47 per cubic yard of 2,700 pounds. The lower 15 inches of sand has an effective size of 0.58 m. m. and a uniformity coefficient of 1.5 and supports a 9-inch layer of sand of an effective size of 0.39 m. m. and a uniformity coefficient of 1.5. The sand rests on a strainer system which comprises brass pipes into which are screwed 152 Beehive strainers.

In April, 1908, the above 24-inch layer of quartz sand became so clogged that its complete removal was necessary. It was then decided to reconstruct the filters placing a graded gravel layer directly over the strainers. This gravel layer is 10 inches in thickness and consists of 5 inches from ½ to 1 inch in diameter, 2½ inches from ¼ to ½ inch and 2½ inches from 1/16 to ¼ inch. On this gravel is placed 28 inches of quartz sand.

The sand taken out of the filters at this time was put back on top of the gravel. Of course, by this handling the two grades originally used became mixed.

From the standpipe the settled and softened water flows through an 8-inch inlet to the filters. The filtered water flows from the filters through a 6-inch pipe, whence it flows by gravity directly to the village. Wash water is admitted through a 4-inch pipe and dirty water is removed by a 4-inch drain. The different pipes for controlling the operation of the filters are provided with hand operated valves. The filters are washed with unfiltered water direct from the standpipe and to assist in washing operations hand operated rakes are provided. The sand in the filters is, of course, completely submerged at all times and there is a direct connection between the water in the standpipe and the filters and that in the mains so that the rate of filtration is dependent upon the consumption. (See Plate XXIII).

Solution Tanks.

Two sets of solution tanks are in use, one for lime and two for soda.

Lime Tank. The lime tank is of 2-inch cypress and is 10 feet in diameter, 18 feet total depth, 16 feet 5 inches deep to the flow line and of 9,700 gallons capacity. Water for preparing the lime solution is unfiltered softened water which is the waste from a Pelton wheel used to furnish power for operating agitating devices for the lime and soda tanks. Thus the waste water eventually becomes lime water. The milk of lime solution is agitated by revolving arms operated by pulleys and gears belted to the shaft which carries the Pelton wheel. The lime solution flows from the mixing tank at a point 2 feet below the flow line through a 4-inch cast iron pipe 150 feet in length which terminates at the mixing box.

Soda Tanks. The two soda solution tanks are constructed of 2-inch cypress, each 4 feet in diameter, 7 feet 6 inches deep and each of about 700 gallons capacity. They are fed by softened unfiltered water and are agitated by revolving arms. The soda tanks feed one small ball cock tank 3 feet in diameter and 2 feet deep whereby there may be effected a uniform rate of flow of soda solution. The solution flows from the control tank through about 150 feet of 2-inch wrought iron pipe to the mixing box.

Pelton Wheel.

The Pelton wheel used for power for the agitators is 12 inches in diameter and is operated with water under a pressure of from about 9 to 22 pounds per square inch, and consumes about 50 gallons of water per minute. It operates all of the stirring devices through a main shaft to which the stirrers are connected by belting. Ordinarily the wheel makes 108 revolutions per minute. The speed of the lime agitator shaft is 38 revolutions per minute, and that in the soda tanks 13 revolutions per minute.

EXAMINATIONS AND INSPECTIONS.

During the investigation visits to the Oberlin water softening plant were made in 1906 on April 14 and Aug. 22-24; in 1907 on Jan. 15-18, March 19-20, June 14, Aug. 20–21 and Oct. 23. The visits of April 14, 1906, June 14, 1907, and Oct. 23, 1907, were inspections only, but the remainder were detailed examinations which covered all features of operation and efficiency. Further information as to this plant has been obtained from time to time by correspondence.

METHOD OF CONDUCTING EXAMINATIONS.

The four detailed examinations embrace a study of features of operation, the collection of samples of the raw, settled and softened waters and samples of the chemical solutions used.

Collection of Samples.

Samples for chemical analysis included the raw water, effluent from settling basins, effluent from filters and samples from the service mains at a number of different points in the town. Ordinarily raw water samples were collected at half hourly intervals in equal portions for a period corresponding to that during which the water was flowing into the settling basins. Samples of the effluent from the settling basins and from the filters were ordinarily collected at 3-hour intervals during a 12-hour run. The examinations usually lasted for two days.

On the first day in the morning and afternoon, respectively, a sample was collected from a fountain in the public square; on the second day, a number of samples were collected at different points in the distribution system.

In addition to these samples, portions of the milk of lime as applied were collected at half hourly intervals. Samples of the soda ash solution were also collected at each examination, together with samples of the dry lime and soda ash.

Bacterial and Chemical Analyses.

Chemical analyses embraced the following determinations: Alkalinity, using both phenolphthalein and methyl orange as indicators, incrustants, magnesium, color, turbidity and iron. Of these constituents, the alkalinity was determined in the field and the other determinations were performed at the laboratory of the State Board of Health on samples shipped by express. Other chemical tests included an assay of the milk of lime solutions, the strength of which was determined by titration with N/20 sulphuric acid, using phenolphthalein and sugar. Precautions were taken in this work in accordance with the technique of the Seyler method.

Bacterial plates were poured in duplicate and were plated at once in the field. On some of the tests, 100 c. c. samples were collected and shipped on ice to Columbus for a qualitative test for the presence or absence of *B. coli*. In general the analytical methods conformed strictly to the standard methods.

OPERATION.

The operation of the water works is under the direction of the village water board and is under the direct charge of the superintendent of the water works who is also the village engineer. The force employed comprises a day engineer, a night engineer and one filter attendant who has charge of applying chemicals, washing the filters and the general upkeep of the grounds. Additional labor is engaged occasionally when it is necessary to clean the reservoirs, mixing box, or carry out any other unusual features with reference to the operation of the plant.

Average Daily Consumption.

In the annual reports of the superintendent the daily pumpage is tabulated as monthly averages from daily records kept at the pumping station. There has been a decided increase in the use of water by the village and from 1902 to 1907, the average daily pumpage has increased from 110,600 to 208,000. Exclusive of the water used for preparing lime solutions and included in the above pumpage data since 1903, the actual consumption has increased from 110,600 to 193,000 or from 40 to 57 gallons to each consumer or 23 to 37 gallons per day to each inhabitant.

The monthly pumpage data for 1907 are as follows:

TABLE NO. 1.

Maximum, Minimum and Average Pumpage by Months for the Year 1907.

Months.	Gallons.			
	Maximum.	Minimum.	Average.	Total.
January	236,000	152,000	204,000	6,323,000
February	239,000	177,000	217,000	6,084,000
March	243,000	118,000	202,000	6,268,000
April	253,000	175,000	216,000	6,481,000
May	256,000	173,000	221,000	6,850,000
June	253,000	156,000	205,000	6,146,000
July	226,000	158,000	191,000	5,911,000
August	302,000	106,000	201,000	6,221,000
September	234,000	135,000	195,000	5,856,000
October	283,000	188,000	214,000	6,728,000
November	270,000	169,000	211,000	6,540 000
December	329,000	162,000	213,000	6,606,000

Maximum daily pumpage	329.000	gallons.
Minimum daily pumpage	106,000	"
Average daily pumpage	208,000	"
Less quantity used for lime water	193,000	" (est.)
Total quantity pumped for the year	76,000,000	"
Less lime water (est.)	70,586,000	"

Chemicals Used.

Since the plant was first operated lime and soda ash have been used as softening agents. In the winter months of 1906 and 1907 and 1907 and 1908, the above chemicals were supplemented by copperas.

Lime. Lime is purchased in barrels from the Marblehead Lime Company at a cost of $1.03 per barrel of 180 pounds, or $11.44 per ton f. o. b. Oberlin. Several analyses of this lime indicated that its average strength is 89 per cent. available calcium oxide (CaO).

Since about September 1, 1907, hydrated lime has been used. This product was found on analysis to contain 69 per cent. calcium oxide (CaO), or an actual purity of 91 per cent. allowing for water of hydration.

Soda Ash. Soda ash is obtained from the Solvay Process Company at a cost of 1 cent per pound f. o. b. Oberlin, on a basis of 58 per cent. Na_2O.

Preparation of Chemical Solutions.

Lime previously slaked in cold softened but unfiltered water in quantities of about 80 pounds is allowed to flow into the lime solution tank at 2-hour intervals during a softening period of 6 hours. The solution tank is always full as it receives the wastes from the Pelton wheel which is constantly in operation during the application of chemicals. The quantity of water so used averages about 3,000 gallons per hour.

During the four detailed examinations at Oberlin, samples of the milk of lime were collected at half hourly intervals and were examined as previously

described. The analyses indicate that there is a decided variation in the strength of the lime solutions as applied to the raw water. Evidence available from this investigation indicates the strength of the lime solution in available calcium oxide (CaO) to range from 56 to 870 grains per gallon. The averages during the examinations were 91, 325, 112 and 262 grains per gallon. As these figures suggest, lime is applied to the Oberlin water in the form of a milk which varies in strength within wide limits, especially after a new charge of slaked lime has been admitted to the lime solution tank. A greater strength of lime has prevailed since July, 1906, when the actual period of softening was reduced, a feature which, of course, necessitated a corresponding increase in the actual solution strength of the applied softening chemicals. Since hydrated lime has been used, the charges are placed directly into the solution tank.

Soda. The rate of application of the soda solution is fairly constant at about 250 gallons per hour. The solution has ranged in strength from 0.8 to 1.3 per cent. depending upon the treatment. The lime and soda solutions, respectively, flow by gravity to the mixing box. The lime is applied behind the first baffle and the soda behind the second.

Application of Chemicals.

As described by the superintendent in a paper on the Oberlin water softening plant,[1] the method of softening originally practiced was to apply the softening chemicals continuously during the daily period of treatment which was usually from 9 to 6 hours duration. At that time, the lime and soda ash solution tanks were recharged at 3-hour intervals. In effect, the treatment comprised the application of the softening chemical continuously during the flow of raw water into the settling basins.

In the latter part of July, 1906, there was a decided change in the method of softening. The superintendent then chanced upon the plan of applying during six hours the total quantity of chemicals required for a 12-hour period. In effect, this meant that the charges of lime and soda ash during a 12-hour period of treatment are twice as great as formerly and that in the second 6 hours of the 12-hour run, raw water alone is allowed to enter the mixing box. The general principle of this plan of "over-treatment" has since prevailed. As it has varied somewhat from time to time it will be of interest to record certain changes in this regard as are shown in the following table. During the greater part of 1907 at times the total period of softening has been much less than 12 hours depending upon the consumption. Ordinarily the softening treatment is begun at 7:00 o'clock A. M.

(1) The Municipal Water Softening Plant at Oberlin, Ohio, W. B. Gerrish, Jour. N. E. W. W. Assoc., Vol. XIX, No. 4, p. 424.

TABLE NO. 2.

Details of Method of Applying Chemicals.

Date.	Hours of Application.			Ratio Period of Treatment to Total Period.
	Chemicals.	Raw Water.		
		Total.	Without Chemicals.	
Aug. 1—Oct. 1, 06	6	12	6	1 to 1
Oct. 1-12, 06	No treatment	.....	.....	.....
Oct. 13-21, 06	6	12	6	1 to 1
Oct. 22-25, 06	No treatment	.....	.....	.....
Oct. 26—Nov. 17, 06	6	12	6	1 to 1
*Nov. 17, 06 Mar. 19, 07	3	10	7	3 to 7
Mar. 19 to date	6	12	6	1 to 1

*NOTE: High water in the reservoir necessitated reducing the operating period to less than 12 hours, hence application of total chemicals for 3 hours only followed by 7 hours of raw water alone.

Application of Copperas. From about the middle of March, 1907, an attempt was made in an experimental way to reduce the residual caustic alkalinity in the filtered water by means of copperas or sulphate of iron. It was stated that while raw water was being applied subsequent to the addition of chemicals a solution of copperas was allowed to enter the mixing box to the extent of about 50 pounds daily. As suggested during one of the detailed examinations, the point of application was subsequently changed and the chemical was for a short time, until the latter part of the spring of 1907, placed into the floating outtake from the south basin, whence it was dissolved and passed into the perforated inlet of the north basin and was thus fairly well distributed.

In resuming copperas treatment in the fall of 1907, the chemical was spread along the dividing wall between the two settling basins and there awaits the solvent action of the raw water, which overflows this wall several hours after treating has begun. It is stated that this method of introducing copperas is very successful, as regards distribution.

MIXING BOX.

The steel mixing box in which the lime and soda ash are applied to the raw water requires little attention except at perhaps intervals of one year when it is necessary to remove adhering precipitates. In his description of the plant, the superintendent states that the tank was first cleaned in October, 1904, when there was found on the bottom a hard deposit about 1/16-inch in thickness surmounted by a soft deposit from ¼ to 1-inch in thickness. The box was again cleaned on September 21, 1905, when sufficient deposit of lime was found at the end of the baffles and at the outlet to almost cut off the flow. The mixing box was again cleaned in December, 1906, and again on August 24, 1907. At the last cleaning it was noted that the deposit was much less in quantity and softer

than previously found. During 1906 and 1907 practically no trouble has been experienced in stoppage in the mixing box by these deposits.

Settling Basins.

The raw hard water flows from 8 to 12 hours daily through the mixing box into the settling basins. The general level of the water in the basins and pump well is low in the morning before the day's treating begins, so that there is always sufficient available capacity to allow sufficient water to be treated for one day's consumption. The pumps are generally operated for two periods in the morning, a total of about 6 hours and for periods of 2 hours each in the afternoon and evening, respectively, or about 10 hours daily. In all cases the pumps are operated until the standpipe is full. The water level in the settling basins is generally about 2 feet below the central dividing wall in the morning, but after about 5 to 6 hours, water begins to flow over the wall and finally the level on both sides is the same and the wall is submerged several inches. The reservoirs have been partially cleaned from time to time in order to remove deposits which have been of frequent occurrence in the perforated distributor in the south end of the first basin. Ordinarily, it is necessary to remove obstructions in the perforations in the distribution pipe every two weeks. In the paper by the superintendent it is stated that the precipitation in the first basin averages about 12 inches per month and that that in the second basin averages only about 0.2 inch per month.

During this investigation, stoppages in the distribution pipe made it necessary partially to clean the basins in May, August and October, 1906, and again on March 20, April 7-8 and November 10-11, 1907. According to information obtained from the superintendent, the basins have not been completely cleaned in recent years. The cleaning of the basin on March 20, 1907, followed an examination of the plant when measurements of the flow of raw water indicated that there was some stoppages in the inlet piping. The water was first drained off and there remained a deposit of brownish sludge 24 inches in thickness and of such a consistency that it would not readily flow. Raw water was then admitted to dilute the sludge and by means of pushers which consist of wooden boxes attached to poles and operated by hand, the surface sludge was forced towards the drain, thence to the creek. The deposits were removed chiefly from that part of the basin near the distribution pipe with a view to exposing the pipe and thus permit of the removal of obstructions. When the sludge had been sufficiently withdrawn from the basin, sewer rods with a root cutter attached were forced up through the vitrified pipe which leads to the mixing box. Near the junction of the mixing box and this pipe there was found a very hard deposit of about 2 inches in thickness, such as to cause a decided stoppage in the raw water flow. Interesting points relative to this deposit were learned from the superintendent who states that it is formed only at points of high velocity and is especially noticeable in the case of iron pipes; it forms less readily, if at all, on stone masonry and but little on concrete. An analysis of the sample, made by the laboratory showed it to be substantially carbonate of lime containing mere traces of magnesium and sulphates.

As there has been no regularity in the extent to which the basins have been cleaned, it is not possible to state the actual quantities of sludge which have accumulated in terms of million gallons of water softened. To learn the approximate composition of the sludge, although the data would undoubtedly be influenced by a compacting factor, especially owing to the somewhat indeterminate length of time since deposited, there were collected for analysis three samples of the sludge, one each from the west and east ends of the south basin, respectively, at the bottom and one at the south end 6 inches below the surface of the sludge.

On analysis, this sludge was found to range in specific gravity from 1.13 to 1.17 with corresponding percentages of water of from 82 to 75. The weight per cubic foot ranged from 70.5 to 73.0 pounds as was found in the case of the bottom sample at the west end of the basin adjacent to the inlet.

The sludge "pushed" from the basin is discharged into Plum Creek which runs through the village and the discoloration of the stream thus produced has caused considerable adverse criticism and has been so strongly objected to by the citizens of Oberlin that it is customary to await a period of flood flow before attempting to clean the basin.

The Filtration of Softened and Settled Water.

Under ordinary conditions, the operation of the pressure filters relates chiefly to washing. Since first used, however, trouble has been experienced owing to incrustation by carbonates in the applied water. Clogging due to these deposits has necessitated the removal of the entire body of sand and the cleaning of the strainer system and, of course, has materially affected the percentage of wash water and the rate of filtration.

Incrustation of Sand. As discussed by Gerrish,* shortly after the filters were first operated, the effective size of the sand gradually increased until after 14 months it had increased from 0.37 to 0.55 m. m. and the uniformity coefficient from 1.6 to 2.0, or roughly 25 per cent. It had then become difficult to move the hand operated rakes during washing and from time to time it was necessary to remove sand from the filter. Conditions similar to these prevailed during 1906. On the detailed examination of January 16, 1907, a sample of the sand which had been removed from the filters showed an effective size of 0.48 m. m. and a uniformity coefficient of 1.7 and a loss of 47 per cent. by weight when treated with hydrochloric acid. It was then learned that no coarse material was placed over the strainer system before the sand was placed in the filters and that on a partial cleaning some time prior to this investigation, the strainers were found to be clogged with carbonates and fine sand. Similar conditions apparently existed on the visit of March 19-20, 1907, and at this time it was recommended to replace the coated sand with clean sand. The clogged filters, however, continued in service until June 10, 1907, when the sand was removed from both. The bottom of the filters were found covered with a thick hard deposit of sand cemented by carbonate of lime. Over the strainer cups the deposit attained a height of perhaps 7 inches. The strainers were greatly clogged and the coarser material which originally formed the bottom layer had become mixed with the finer portion so that the entire body of the sand was substantially the same effective size.

The strainers were cleaned in dilute muriatic acid. The filters were then filled to a depth of 32 inches with lake sand, which on analysis showed an effective size of 0.25 to 0.30 m. m. and a uniformity coefficient of 1.4. This sand cost 85 cents per ton on cars or $1.00 per ton delivered at the plant. To increase the effective size there was attempted to wash out the finer particles in place and to effect this the sand was placed into the filter in three layers. Considerable fine sand was so removed, but the surface sand was found to be quite fine and to have an effective size of only 0.24 m. m. and a uniformity coefficient of 1.3. No coarse material was placed around and over the strainer cups and it was suggested that this fact would probably tend to cause clogging in the strainer system and would require a greater number of washings and a greater volume of wash water.

The filters after this reconstruction period continued in use until the latter part of November, 1907, when clogging was so much in evidence and the loss

*Loc. cit.

of head was so great that it was decided to remove the sand and replace with a coarse grade of Cape May sand. This was carried out in the middle of December, 1907, as already described.

In April, 1908, the Cape May sand became greatly clogged and the loss of head was so great that it was necessary to remove the sand as before stated. Samples of the surface sand were examined in the laboratory of the State Board of Health and were found to contain 18.9 per cent. calcium carbonate and 2.6 per cent. oxide of iron (Fe_2O_3). Similar samples collected immediately over the strainers contained 7.1 per cent. calcium carbonate and 0.2 per cent. oxide of iron. These figures suggest that the coating of the sand is not due wholly to the arrestation of suspended carbonate of lime, but that the dissolved carbonates are themselves precipitated and the water in the absence of carbonic acid may contain a potential precipitate of calcium carbonate. These results are instructive in view of troublesome deposits and incrustations at other water purification plants where lime is used as a coagulant, or as a softening agent.

Rates of Filtration. The pressure filters are operated under a head of from 54 to 68 feet and as before stated the rate of filtration depends upon the consumption by the town. Several measurements have been made of the head of water on the sand when the pumps are shut down, and the water was being lowered in the standpipe, due entirely to the consumption by the village. On January 17, 1907, measurements were taken at 15-minute intervals for two hours; the average rate of fall with both filters in service was 0.09 foot per minute, or 171 gallons per minute, or a rate of filtration of 140,000,000 gallons per acre per day.

On the next examination, the filters were badly clogged. Similar observations showed a rate of filtration which ranged from 39 to 76 gallons per minute, or from 32,000,000 to 62,000,000 gallons per acre per day. Observations made by the engineer of the plant after the filters were reconstructed in the fall of 1907, showed a rate of filtration for both filters of 253 gallons per minute or about 288,000,000 gallons per acre per day.

Percentage of Wash Water. As prevailed until the filters were resanded in the summer of 1907, the filters were cleaned about three times each week. Since that date it has been necessary to blow once daily, but during the fall of 1907 it was necessary to wash twice each day. The filters are washed with softened but unfiltered water. Since one filter is out of service at a time, the entire quantity of water filtered temporarily passes through one unit.

On the detailed examination of August 20, 1907, data were obtained as to the washing of the filters and the percentage of wash water after the original Cape May sand had been replaced with finer lake sand. It was then the practice to wash the filters once daily. On August 21, with pumps out of service, the east filter was washed and required 3.9 minutes; the west filter similarly required 8 minutes. It will be noted that the west filter was washed at a rate of about one-half that of the east filter, due to the fact that the former showed more clogging. During washing, the rate of fall of the water was noted in the standpipe which has a capacity of 1904 gallons per foot. After washing, the fall of the water level in the standpipe was also determined to learn the town consumption during washing. Computed from these data, the easterly filter required 2,570 gallons and the westerly filter 3,140 gallons, although washed practically twice as long.

These data are especially instructive as indicating the clogged condition of the westerly filter and suggest that the efficiency of the washing was much less than in the easterly filter. On the basis of an average daily consumption of 200,000 gallons the percentage of wash water was about 2.8.

There are no loss of head gages for the filters and the pressure gage on

the mains does not, of course, indicate the loss of head in the filters since the actual pressure then recorded is a direct function of the water consumption.

Expert Control.

At Oberlin, the application of the softening chemicals have generally been based on the end results of the softening rather than upon the composition of the raw water. Since the plant was first operated, the city engineer has made daily tests to determine the alkalinity of the softened product using both phenolphthalein and methyl orange as indicators. Occasionally, the incrustants and the total magnesium were also determined. Changes in the quantities of chemicals applied have generally been somewhat infrequent since the impounded raw water is sufficient to supply the village for 75 days.

With a view to making more precise the character of the chemical control of the plant, in November, 1906, the State Board of Health advised more extensive tests. Accordingly, the city engineer increased the tests to include the following daily determinations: Total alkalinity, phenol alkalinity and caustic alkalinity. Several times each week magnesium and incrustants are determined. It is the usual practice to determine the above constitutents in the case of the raw and treated water, respectively, on alternate days. The Board also advised that the composition of the raw water be made the basis of treatment and suggested factors to be used in connection with the composition of the raw water. This suggestion was acted upon and the practice has prevailed during 1907, except for two weeks in September when in the absence of the superintendent, no water softening was attempted.

THE SOFTENING PROCESS.

Water softening at Oberlin is effected by the use of lime and soda ash, the former for the precipitation of the carbonates and the magnesium and the latter for the removal of the incrustants. The mode of applying the chemicals for water softening on the continuous flow basis since July, 1906, has differed somewhat from general practice, in that 100 per cent. of the computed quantity of chemicals has been added to 50 per cent. of the water, following which the remainder of the raw water has been applied with a view to neutralizing the excess of chemicals first added. This process takes advantage of the well known principle of the greater speed of chemical reaction when the reagent is present in decided excess. It is of special importance with reference to residual caustic alkalinity in the softened water and the feature of after-reactions and accompanying troublesome deposits.

Chemical Considerations.

The process here practiced offers no special features in a chemical way, but for the sake of completeness, the chemical processes on which are based the softening treatment, will be briefly stated.

Lime Reaction. The lime first neutralizes the free and the half-bound carbonic acid in the raw water, effects a precipitation of the carbonate of calcium and is itself in part precipitated as such. It also converts the total magnesium in hard water to the insoluble hydrate, and in this reaction there is formed an equivalent quantity of a calcium incrustant. In computing the quantity of lime required for a complete lime softening, it is, therefore, necessary to base the treatment on the total carbonic acid (free + half bound) and on the total magnesium. The lime reactions in the case of the Oberlin water are as follows:

$$CaCO_3 + CO_2 + Ca(OH)_2 = 2CaCO_3 + H_2O$$
$$MgCO_3 + CO_2 + Ca(OH)_2 = MgCO_3 + CaCO_3 + H_2O$$

$$MgCO_3 + Ca(OH)_2 = Mg(OH)_2 + CaCO_3$$
$$CO_2 + Ca(OH)_2 = CaCO_3 + H_2O$$
$$MgSO_4 + Ca(OH)_2 = Mg(OH)_2 + CaSO_4$$

Soda Ash Reaction. Soda ash precipitates the calcium component of the incrustants and converts to a basic carbonate form the magnesium component. The latter as just stated, is precipitated by lime with the formation of an equivalent quantity of a lime incrustant, which is then precipitated by soda ash. The basis of soda ash treatment consequently is the total incrustants in terms of calcium carbonate regardless of the relative quantities of the calcium and magnesium components. The reactions which take place when soda ash is applied to the Oberlin water are as follows:

$$MgSO_4 + Na_2CO_3 + Ca(OH)_2 = Mg(OH)_2 + CaCO_3 + Na_2SO_4$$
$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$$

Factors. To determine the quantity of chemicals required to treat a magnesium water, it is convenient to derive factors for the conversion of the constituents of the raw water expressed in parts per million to their equivalent in lime or soda ash expressed in grains per gallon.

The quantity of lime required is that necessary to neutralize the carbonic acid, which is the sum of the free carbonic acid and 44 per cent. of the alkalinity which is assumed to represent the half-bound carbonic acid. When the quantity of carbonic acid is expressed in parts per million, the quantity of lime required expressed in grains per gallon may be obtained by using the conversion factor 0.074. The magnesium–lime factor is similarly 0.136. To obtain the quantity of lime required to precipitate the magnesium, *the total magnesium* is to be multiplied by this factor.

To determine the quantity of soda ash in grains per gallon the quantity of incrustants in parts per million is to be multiplied by the factor 0.062.

Character of Raw Water.

The impounded supply of Oberlin is of fairly constant composition and is subject only to few gradual changes, except perhaps during the heavy rains of spring and during the spring and fall overturn. There is, however, some difference in the hardness of the water under winter and summer conditions. The water derived from swampy land near Kipton and considerably diluted by the infiltration of ground water through leaks in the pipe line, generally has considerable color, especially in the fall, contains relatively large quantities of vegetable matter and in hot weather has a decided odor and an objectionable taste. In recent years, considerable annoyance during the summer months has been occasioned by growths of *Chara* and numerous other organisms which have developed in the storage reservoir. Attempts to remove algal growths, particularly the *Chara*,[1] by means of copper sulphate were only partially successful as the roots of the plant were not destroyed. Conditions with respect to tastes, odors and vegetable growths were not so pronounced in the summer of 1907, as was the case in former years.

On the four detailed examinations the total hardness of the raw water ranged from 233 to 271 parts per million; the alkalinity from 146 to 176; the incrustants from 80 to 95; the magnesium from 10 to 32. The color in the colder months ranged from 30 to 55 and in the summer of 1907, was only 10

[1] *Copper Sulphate Symposium*, Jour. N. E. W. W. Assoc., Dec. 1905, Appended Tabular Statement.

parts per million. The turbidity is generally about 20 parts per million, but in very wet weather is at times somewhat increased. There appears to be generally a slight decrease in hardness in the summer months, except in dry seasons. The water is generally neutral to phenolphthalein, although occasionally there have been noted from 6 to 8 parts per million of alkalinity to this indicator. In August, 1906, when there was made the first detailed examination, tastes and odors were particularly marked. It was, therefore, thought of interest to have made a partial microscopical analysis, together with a complete analysis of the raw water. These analyses are appended to this report. The microscopical examination indicated the water to contain from 10,000 to 15,000 organisms of a great variety of species sufficient to account for the odors and tastes then noticed in the untreated water.

Quantity of Applied Chemicals.

The general practice at Oberlin is to apply sufficient reagents to precipitate the greater part of the hardness and to obtain a softened water which will have an alkalinity from 40 to 50, incrustants from 5 to 10 parts per million and but a small residual quantity of magnesium.

The quantity of lime and soda ash added has not varied widely during 1906 and 1907, as would be expected from the fairly constant composition of the raw water. Data as to the quantity of applied chemicals corresponding to the quantity of water treated and the changing method of applying chemicals, are illustrated by information obtained on the four detailed examinations and shown in the following table.

TABLE NO. 3.

Quantity of Applied Chemicals.

Date of Examination.	Gallons Treated.	Hours Raw Water Applied.	Hours Chemicals Applied.	Chemicals Applied.			
				Pounds per hour.		Grains per Gallon.	
				Lime.	Soda Ash.	CaO.	Na_2CO_3.
Aug. 23-24, 1906	161,000	8	4	40	17	6.2	2.9
Jan. 16-17, 1907	217,000	10	3	120	70	10.3	6.7
Mar. 19-20, 1907	135,000	8	4	61	29	11.2	5.9
Aug. 20-21, 1907	233,000	12	6	62.5	20	10.2	3.5

The following table which shows the average quantity of lime and soda ash applied to the Oberlin water during the years 1906 and 1907 has been compiled from records kept at the plant and made available for this report through the courtesy of the superintendent. It is of interest to note that there is only a slight variation in the quantity of softening chemicals applied, except as corresponds to the seasonal changes in the character of the raw water and the irregularities in the treatment which has already been discussed. During a large part of 1907, a full reduction of incrustants was not deemed advisable as suggested by the reduced quantity of soda ash applied.

TABLE NO. 4.

Average Quantity of Lime and Soda Ash Applied by Months During 1906 and 1907.

Month.	Total Pounds Chemicals Applied.		Pounds Chemical Daily.		Lime.		Soda Ash.	
	Lime.	Soda Ash.	Lime.	Soda Ash.	Grains per Gallon.	Tons per Million Gallons.	Grains per Gallon.	Tons per Million Gallons.
1906								
January	9,725	3,260	347	117	13.6	0.97	4.6	0.33
February	9,085	3,260	324	117	11.8	0.84	4.3	0.31
March	9,340	4,205	300	136	11.0	0.79	5.0	0.36
April	8,375	3,530	299	126	12.0	0.86	5.1	0.36
May	9,120	3,950	365	158	13.8	0.99	6.0	0.43
June	10,080	4,200	347	145	12.2	0.87	5.1	0.36
July*	.....	.....	.....	.....	.....	.....	.....	.....
August	6,600	2,740	236	98	9.5	0.68	4.0	0.29
September ...	7,560	3,060	252	102	8.9	0.64	3.6	0.26
October	7,060	3,120	415	183	15.9	1.14	7.0	0.50
November ...	11,595	4,305	386	143	13.6	0.97	5.0	0.36
December ...	8,660	5,285	289	176	10.6	0.76	6.4	0.46
Average ..	8,840	3,720	324	136	11.2	0.86	5.1	0.37
1907								
January	8,800	5,261	284	169	10.1	0.72	6.0	0.43
February	6,657	3,984	238	142	8.1	0.58	4.8	0.34
March	7,400	2,704	247	123	9.2	0.66	4.6	0.33
April	6,199	3,027	229	111	8.0	0.57	3.9	0.28
May	5,839	2,421	188	78	6.0	0.43	2.5	0.18
June	4,458	1,903	182	63	6.6	0.47	2.3	0.16
July	5,485	1,790	189	62	7.4	0.53	2.4	0.17
August	8,001	2,621	276	90	11.0	0.79	3.6	0.26
September ...	5,874	2,080	280	99	10.8	0.77	3.8	0.27
October	10,100	3,120	326	100	11.5	0.82	3.5	0.25
November ...	10,050	4,460	359	159	12.9	0.92	5.7	0.41
December ...	12,300	5,591	397	180	14.0	1.00	6.4	0.46
Average ..	7,680	3,330	266	115	9.6	0.69	4.1	0.21

* No treatment.

On each examination, the theoretical softening has been computed from the analysis of the average sample of the raw water in conjunction with the quantity of water treated. (Determined by observing rate of filling of north basin when pumps are stopped). Although at times it was found that the chemicals were applied in approximately correct quantities, yet at other times changes in the raw water caused the use of an excess of lime owing in part to the fact that there is too little expert control as regards the chemical composition of the raw water. At other times, too small quantities of softening chemicals have been applied.

On the first examination insufficient chemicals were applied to effect a maximum softening. The raw water on analysis contained in parts per million, free-

and half bound carbonic acid 85; magnesium 22; incrustants 70. Based on chemicals of 100 per cent. strength there were added 6.2 grains of lime and 2.9 grains of soda ash per gallon. Computed from the above chemical data, the actual quantity of lime applied, (100 per cent. CaO) should have been 9.3 and correspondingly, the soda ash should have been 4.3 grains per gallon.

Representing conditions illustrating an excess of reagents are the results of the examination on January 16-17, 1907. Expressed in parts per million, the analysis of the raw water was as follows: free and half bound carbonic acid 70; magnesium 33; incrustants 87. The theoretical quantity of lime and soda ash required to soften this water was 9.7 and 5.4 grains per gallon, respectively. There were added 10.3 and 6.7 grains per gallon, respectively, or expressed in pounds of 100 per cent. chemicals, 320 pounds of lime and 207 pounds of soda, an excess of 20 pounds of lime and 40 pounds of soda based on 217,000 gallons of water treated.

On the third examination the lime was in excess by about 2.7 grains per gallon and the soda was practically the theoretical quantity. On the following test the lime applied was about the theoretical quantity, but the soda ash was less than necessary to effect a maximum softening.

Period of Reaction and Subsidence.

The time factor is usually understood to be of importance in water softening, especially in cold weather when the temperature of the water is near that of maximum density and when chemical reactions are greatly retarded. Under Oberlin conditions, the combined capacity of the settling basins affords a total reaction period of three or four days on the assumption of complete displacement. This condition is, of course, rarely if ever attained in practice, and at Oberlin there are several facts which appear to interfere with even a normal displacement by the incoming water.

As developed during this investigation, the connection between the iron inlet pipe from the mixing box and the perforated distribution pipe in the south basin, is ordinary vitrified sewer pipe, with loose joints which are broken in places and this fact, in connection with the clogging of the distribution pipe itself, causes the greater part of the water to enter the basin at one point near the west end. The outtake is so located, however, as to compensate in part for the poor distribution which prevails at the inlet, but this outtake is used only for perhaps from 5 to 6 hours during treatment, after which, the water flows in a thin sheet over the transverse dividing wall. In the absence of baffles, there is set up in the basin a whirlpool action which has a tendency to cause vortical currents, and on account of the over-treatment now practiced, as will be presently discussed, superlimed water frequently flows into the second basin, and on this account the actual period of reaction is decidedly less than the theoretical. The fact that the treatment is continued daily for from 8 to 12 hours only, however, tends to offset poor displacement during the actual period of chemical application. As will be presently brought out, in considering the efficiency of the softening, it would be a decided advantage did there exist better piping connections between the mixing box and the south reservoir, and further were there constructed a submerged transverse baffle a short distance from the inlet of the first basin. Raising the distribution pipe would probably greatly improve present conditions.

EFFICIENCY.

In discussing the efficiency of the Oberlin water softening plant available evidence will be reviewed, first as to strictly water softening features as they effect the physical, chemical and bacterial character of the water and second,

as to general features of the Oberlin water supply, as regards the health of the village and the use of the water by the consumer.

Physical Characteristics.

Aside from the removal of hardness, the treatment at Oberlin to a certain extent serves to improve the physical appearance of the raw water. Information obtained during this investigation indicates that the process cannot remove more than 50 to 75 per cent. of the dissolved color, especially during the warmer months when the dissolved color is low. It has also been brought out that while the combined water softening sedimentation and filtration through the pressure filters removes the greater part of the algae and crustacea, yet this treatment is not capable of removing tastes and odors derived from oil secreted by organisms in the raw water. Odors and tastes have generally been especially marked in the summer months and in a large part may be attributable to the presence of *Chara* in the reservoir. Conditions in this regard were exceptionally pronounced in the summer of 1906. The tastes and odors in the softened water gradually decrease as cold weather approaches and are always less in the winter and spring. During the summer of 1906 the water was drawn from the bottom of the storage reservoir and this fact probably largely accounts for the excessive tastes and odors then noted. Since that time, the floating outtake has been used and conditions as to odors and tastes were less pronounced in the summer of 1907. There was, however, a decided development of *Chara* and other organisms and the water had a distinct vegetable taste when warm and some odor, but neither were especially objectionable. According to late information, no complaints as to odors and tastes have been filed since the summer of 1907.

Reduction in Hardness.

The efficiency of water softening with respect to the removal of the hardness constitutents of the raw water is perhaps best indicated by a consideration of the composition of the treated water rather than by an expression of the percentages of removal effected. Of special importance is the presence of unused reagents, especially lime or what is technically known as residual caustic alkalinity.

The degree of softening effect at Oberlin as found on the four detailed examinations has been such as to afford a treated water from the service mains with a total hardness of from 45 to 101 parts per million. The alkalinity has ranged from 35 to 74 and has rarely been reduced to less than 40 parts per million and then during the warmer months of the year. The incrustants have varied somewhat following changes in the quantity of soda ash applied and have ranged from 0 to 45 parts per million. The magnesium in the treated water has ordinarily been reduced to from 3 to 29 parts per million, figures which represent about 50 per cent. of that of the raw water, although during the examination in the summer of 1907 there was removed 72 per cent. of this constitutent.

The element of time in its effect on the removal of hardness by water softening practice has already been mentioned and is well illustrated by data collected on the four detailed examinations. They show a progressive softening as the water successively flows through the settling basins and filters and finally reaches the consumer. These data are shown in condensed form in the following table which covers all information available from this investigation.

TABLE NO. 5.

Average Results of Analyses of Raw and Softened Water Especially Illustrating Progression of Softening.

	Parts per Million.															
	Total Hardness.				Alkalinity.				Incrustants.				Magnesium.			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Raw water	240	235	239	271	160	148	146	176	80	87	93	95	10	33	24	32
Outlet 1st basin	146	172	108	123	99	121	101	86	47	51	35	37	9	15	18	16
Outlet 2d basin	100	120	112	101	75	89	77	61	25	31	35	40	6	18	18	15
Outlet filters	83	104	99	86	59	75	57	47	24	29	41	39	7	15	11	10
Service Mains	51	74	81	74	43	63	49	38	8	10	31	37	4	16	11	9

A — Collected on September 11, 1906.
B — Detailed examination of January 15–18, 1907.
C — Detailed examination of March 19–20, 1907.
D — Detailed examination of August 20–21, 1907.

The following table shows the same data arranged as percentages of removal of hardness.

TABLE NO. 6.

Progressive Percentage Reduction in Hardness.

	Percentage Removal.															
	Total Hardness.				Alkalinity.				Incrustants..				Magnesium.			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Outlet 1st basin	39	27	42	55	38	18	31	51	41	40	62	61	10	55	25	50
Outlet 2d basin	58	49	53	63	53	40	47	65	69	64	62	58	40	45	25	53
Outlet Filters	71	57	59	68	63	49	61	73	70	67	56	59	30	55	54	69
Service mains	79	69	66	73	73	57	66	78	90	88	67	61	60	52	54	72

Residual Caustic Alkalinity.

One of the most important considerations with reference to the efficiency of water softening plants designed for domestic use, refers to the absence at all times of even traces of undecomposed softening chemicals, especially free caustic lime. The presence of what may be termed residual caustic alkalinity in the softened water is probably injurious to health and increases the tendency to "after-reactions" on the part of the softened water. Furthermore, in certain cases it is destructive to fish life.

Experiences at Oberlin have shown that an excess of caustic lime or residual caustic alkalinity is more apt to occur when the temperature of the water is low and chemical action is sluggish. When the plant was first operated, it was thought that it would eventually be necessary to provide for recarbonating the softened water, as is the practice in some places, and while this has not been necessary, sulphate of iron or copperas has been applied during the winter months, as already discussed. It is strongly indicated, moreover, that the feature of "over-treatment" tends in a large measure to hasten chemical action and to offset the effect of cold weather.

The presence of caustic alkalinity is determined by the relation of the alkalinities obtained by the successive use of phenolphthalein and methyl orange as indicators, and as is well known, is shown when the alkalinity by phenolphthalein is more than one-half that by methyl orange.

Winter and Summer Conditions. Analytical evidence has indicated that caustic alkalinity is present to a slight extent in the water as furnished to the consumer, generally during the colder months and at times in summer owing to irregularity in displacement in the settling basins, or to the use of an excess of softening chemicals.

On the examination of August 23-24, 1906, none of the service main samples contained caustic alkalinity and none was found except in the effluent from the first basin. The temperature of the water was about 73 degrees F. On the next examination on Jan. 16-17, 1907, the water was near the temperature of maximum density. Samples of the effluent from the first basin contained from 22 to 34 parts per million caustic alkalinity. The effluent from the second basin contained from 0 to 7 and that from the filters from 0 to 20. The water in the village softened some days previous, contained from 0 to 13 parts per million of residual caustic alkalinity. This result indicates an incorrect softening, poor displacement or lack of time for a complete reaction at the low prevailing temperature. It is to be noted that there was a slight excess of lime used on the above days. On the examination of March 19-20, 1907, iron was being used to correct caustic alkalinity, as before stated, but the point of application at the mixing box after all of the lime and soda ash had been applied, was probably such that very little benefit was obtained. On this test, the different samples collected showed a caustic alkalinity, which ranged in parts per million as follows: first basin, 8 to 45; second basin, 0 to 27, effluent filters, 3 to 12; and service mains, 8 to 11. The temperature of the water was about 42 degrees F. The results on the examination in Aug., 1907, although obtained during warm weather, showed a slight caustic alkalinity in samples collected in the town. In possible explanation, it was brought out that there is a decidedly irregular displacement in the settling basins whereby it is possible for heavily limed water to pass rapidly through the settling basin on to the filters. As has been stated there was no excess of chemicals used at this time.

Later information is to the effect that since November, 1907, when copperas has been applied in accordance with the new method of introducing this chemical, samples of water from the service mains have shown no excess of caustic lime.

Effect of Temperature. Mention has already been made relative to the effect of low temperatures on the degree of softening effected, especially in relation to the presence of residual caustic alkalinity. Instructive data in this regard are available from a comparison of results of the analyses of the samples collected in September, 1906 and during the examination in January, 1907. These analyses are presented in the following table and illustrate also the progressive softening effected and the influence of time as well as the retardation in the softening reaction brought about by a low water temperature. The comparison is suggestive only and would be of greater value were it not for the fact that there was a slight excess of lime used in January and further because of irregularities in the displacement of water in the settling basin as is next discussed.

TABLE NO. 7.

Comparative Efficiency of Softening Under Summer and Winter Conditions.

	Temperature deg. F.		Parts per Million.									
			Total Hardness.		Alkalinity.		Incrustants.		Magnesium.		Caustic Alkalinity.	
	Sept.	Jan.	Sept.	Jan.	Sept.	Jan.	Sept.	Jan.	Sept.	Jan.	Sept.	Jan.
Raw water	70	38	240	235	160	148	80	87	10	33	0	0
1st Basin	71	38	146	172	99	121	47	51	9	15	0	27
2d Basin	71	43	100	120	75	89	25	31	6	18	0	3
Filters	71	44	88	104	59	75	24	29	7	15	0	3
Service Mains	78	41	51	74	43	63	8	10	4	16	0	6

Irregular Displacement in Settling Basins. In connection with the constant presence of an excess of lime in the softened water at different points in the system, it seemed of interest to obtain data as to the efficiency of the displacement in the basins, since a decided difference in the composition of the water transversely across the basin would appear to have a decided influence on the end results of the softening and would furthermore, tend to render uncertain conclusions as to the extent of the influence of cold weather and as to the actual efficacy of after-treatment with copperas. Were currents found in the south basin, the presence of an excess of lime in the north basin could very readily be accounted for, since during the operation of the plant, raw water highly charged with lime and soda ash enters the south basin for several hours following which raw water alone is applied. In case of currents through the south basin, the highly lime-treated water would naturally be forced into the north basin and hence the period of retention in the basin would be far from the theoretical period corresponding to the capacity of the basin and the quantity of raw water treated daily.

Accordingly, on the examination of March 19-20, 1907, at 10-foot intervals across the minor axis of the settling basin on the south side of the dividing wall, there were collected at the depth of about 6 inches and about 6 inches south of the wall, samples of the water in the south basin, during a period when raw water alone was entering the basin. Analyses of these samples are shown below in Table No. 8. They indicate clearly that the displacement in the basin is very irregular and that large quantities of over-treated water continually reach the north basin during the period of raw water inflow, especially in the absence of baffles, that the facilities for displacement are very poor and that there is a great chance that water with a high caustic alkalinity will pass on to the filters. It is thought also that the mode of entrance of the raw water has an important bearing on this point. The results suggested a communication by the State Board of Health to the Oberlin officials of the advisability of constructing a baffle across the south end of the south basin. Similar results were obtained on the examination in August, 1907.

TABLE NO. 8.

Representative Date Illustrative of Irregular Displacement in South Settling Basin.

Distance from East Side (Feet)	Parts per Million.		
	Alkalinity.		
	Phenolphthalein.	Caustic.	Total Methyl Orange.
0	86	41	122
10	88	45	120
20	102	54	138
30	152	94	188
40	84	39	120
50	94	50	126
60	84	44	114
70	84	44	114
80	78	39	108
90	76	44	98
100	80	39	112

Correction by Copperas. Following the first attempt to neutralize the excess of caustic alkalinity with copperas, the point of application was changed to the outtake of the first basin, and as a result there is stated to have been a general absence of an excess of caustic lime. The use of copperas was discontinued in the summer months, but as before stated, it was resumed in the fall of 1907 with an improved method of introduction. It is stated that the copperas as now introduced suffices to prevent residual caustic alkalinity even in cold weather. The quantity of copperas applied is 50 pounds daily, or about two grains per gallon and will neutralize about 0.6 grain or 10 parts per million caustic alkalinity. While according to the superintendent the application of copperas has been very successful in eliminating residual caustic alkalinity, yet it appears that there are some drawbacks to its use as practiced at Oberlin, in that the pressure filters now require one wash each day and for an increased period, due to the presence of iron in the applied water and its subsequent tendency to clog the sand. As has already been stated there is a decided increase in the percentage of wash water due to the use of copperas. Furthermore, the copperas tends to increase the incrustants at the rate of about 17.1 parts per million when the above quantity of the chemical is used daily.

After-Reactions.

One of the most difficult features to control in water softening is a tendency of the treated water to form deposits due to reactions which take place after the water leaves the plant. The discussion and the data which have preceded, indicate a gradual reduction in hardness at Oberlin from the application of the water to the filters and during its passage through the village mains. The gradual reduction in caustic alkalinity and the presence of an excess of caustic lime in the water in the mains, as just discussed, suggests that there is a certain

quantity of potential carbonate of lime in the softened product. It is, of course, to overcome this feature that every effort is made to prevent an excess of caustic lime with a view to insuring a stable water and a properly balanced softening.

Interesting data have been learned from the forthcoming report of the superintendent for the year 1907, as to the deposit in the distribution system and in meters. There has never been noted any general deposition in the small service pipes or in faucets, but some trouble has been experienced with meters. Three makes of meters are in use, of the 70 disc meters, only one clogged, of 270 rotary meters of one make none required cleaning, while out of 390 of another make, 10 per cent. needed attention on account of clogging by deposits of carbonates.

In general troubles due to after-deposits have not been especially serious in Oberlin. The water has been fairly stable, although it has at times contained small quantities of residual caustic alkalinity. In general it is apparent that the excess of lime and the feature of after reactions have not been such as to cause serious results nor sufficient to be destructive to fish life.

Removal of Bacteria.

Bacterial analyses made on the four detailed examinations at Oberlin have shown interesting and instructive data as to the efficiency of the coagulation by the precipitates formed during water softening by lime and soda ash, especially the availability of magnesium as a coagulant. The results at each examination have shown a remarkedly high removal of bacteria by the softening process alone, practically little improvement is effected by the filters, but as supplied to the consumers, the water contains an unusually small number of bacteria. The bacterial content of the untreated Oberlin water is usually low and has ranged from 250 to 1,050 per cubic centimeter. On the four detailed examinations the highest number of bacteria in the effluent from the second basin was 100, a result which is apparently largely due to the entraining power of the gelatinous hydrate of magnesium which is rapidly formed from this magnesium water by the excessive over-treatment with lime, a condition which usually prevails during one-half of the daily period of treatment. The water in the service mains has ranged from 2 to 50 bacteria per cubic centimeter. The raw water very rarely shows evidence of pollution by the presence of B. coli and none has been found in the filtered water during this investigation.

The bacterial efficiency of the softening process as effected at Oberlin is summarized in the following table in which are presented all of the bacterial data available from this investigation. These data are instructive as suggesting that water softening with lime and soda ash, especially in the case of a magnesium water, is productive of precipitates which because of their entraining properties are capable after a reasonable period of subsidence to effect the removal of a large percentage of the bacteria in the raw water and that from a hygienic standpoint, there is but a light load placed upon the filters which in the main are chiefly of importance in improving the water from the physical side by the removal of precipitates remaining in the settled water.

TABLE NO. 9.

Average Removal of Bacteria.

Source.	Number of Samples Averaged.				Bacteria per Cubic Centimeter.				Percentage Removals.			
	A	B	C	D	A	B	C	D	A	B	C	D
Raw water	3	5	3	7	400	760	600	250	.....	.....	.....	.....
1st Basin	1	5	4	7	45	8	47	13	88.8	98.9	92.2	94.8
2d Basin	.....	5	3	7	.....	45	26	17	.....	94.0	95.7	93.2
Filters	1	5	4	7	30	13	5	10	96.5	98.3	99.2	96.0
Service Mains	2	7	7	6	43	9	12	8	89.5	98.8	98.0	96.8

A——Examination of August 23-24, 1906.
B — Examination of January 16-17, 1907.
C — Examination of March 19-20, 1907.
D — Examination of August 20-21, 1907.

The unusually small numbers of bacteria in the Oberlin water as supplied to the consumer, as indicated by the results presented in the above table and in the table of detailed analyses which follow this report, suggest that the Oberlin water is free from bacterial contamination and is safe and wholesome. In this connection, it is of interest to consider the record of typhoid fever in the village as obtained from the records of the local health officer. The following table shows that there has been but a very limited number of cases of typhoid fever in the village during the past eight years, a total of only 57, of which 8 or 14 per cent. were traced to the use of well water, 3 or 5 per cent. to direct infection by contact, and 21 or 37 per cent. to importation from other towns. Moreover, there was only one death from typhoid fever from 1900 to 1907 and this occurred in 1902. In regard to the typhoid statistics, it is to be noted that particular attention is directed by the health department to obtaining a record of all cases of the disease and the probable source of each case. This practice is commendable and is in striking contrast to laxity in this regard in many of the cities and villages in the state.

The following table shows typhoid fever statistics for the past eight years, together with a classification of cases with reference to their probable source.

TABLE NO. 10.

Typhoid Statistics for the Years 1900 to 1907, Inclusive.

Year.	Population.	Cases.				
		Well Water.	Contact.	Imported.	Unknown.	Total.
1900	4,800	3	0	5	1	9
1901	4,800	0	1	2	4	7
1902	4,800	2	1	2	4	9
1903	4,800	0	1	5	7	13
1904	4,800	0	0	1	2	3
1905	4,800	0	0	2	1	3
1906	5,000	2	0	3	1	6
1907	5,200	1	0	1	5	7
Total	.....	8	3	21	25	57

SUMMARY.

In reviewing the results of the four detailed examinations of the Oberlin water softening plant carried out during this special investigation, it is purposed to discuss briefly salient features with reference to the operation of the plant from the standpoint of water softening and to recount briefly the general efficiency of the plant, both as to water softening features and as to the production of a wholesome water from a sanitary standpoint.

The untreated water supply of Oberlin is a hard surface water, in part containing ground water through infiltration, is generally somewhat turbid, contains considerable dissolved color and in the warmer months of the year has a decided odor and a disagreeable taste due to the presence of vegetable organisms.

The purification of this water relates chiefly to a removal of a large part of the hardness by treatment with lime and soda ash on a continuous flow basis for about 12 hours daily. The raw water charged with lime and soda ash is admitted to settling basins which afford a storage of from three to four days, following which it is filtered through pressure filters which are directly connected to the service mains.

The control of the softening has usually been based on the end results rather than on the character of the raw water as shown by chemical analyses, although due to suggestions from the State Board of Health, certain analyses are made whereby the character of the raw water may be made the basis of the chemical treatment. The quantity of raw water to be softened is known from the rate at which the second or north basin is filled from the reservoir. Obstructions in the piping or in the mixing box between the reservoir and the settling tanks, of course, tend to reduce the flow of water which is also further varied on account of the fluctuating level in the reservoirs. Due to the combined causes of insufficient analytical data as to the character of the raw water, and to the varying flow of raw water on account of the conditions just mentioned, at times the quantity of chemicals applied is such as to afford an excess, especially of lime or a deficiency with respect to a maximum practical softening effect.

The filtration of the softened and settled water has been attended with decided difficulties owing to the incrustation of the sand by finely divided carbonate of lime in the water as applied to the filters. This incrustation has decidedly increased the size of the individual sand grains and has necessitated the removal of portions of the sand, until the entire body of sand was removed, the strainers cleaned and the sand replaced with a finer grade of lake sand. This sand was too fine for serviceable results and was removed after about six months' use. It in turn was replaced with a coarse silica sand to a depth of 24 inches, but as true in both instances no special coarse material was placed directly over the strainers. In April, 1908, the filters became so clogged that it was again necessary to remove the sand. In reconstructing the filters, acting on suggestions from the State Board of Health, a graded gravel layer was placed over the strainers and since that time it is said that conditions have decidedly improved.

The lime used at Oberlin has been a high grade product which was in successful use until the fall of 1907, when hydrated lime was tried and was found so readily adaptable to Oberlin conditions, that it has since been used in preference to the unslaked product.

One of the most interesting points in regard to the water softening practices at Oberlin relates to the method of overtreating which in effect is the application to one-half the water the quantity of chemicals required to soften the total volume of water treated. This practice has been used since the summer of 1906, and indications are strong that there has been a much more rapid softening

under these conditions, especially in the colder months. The actual benefit derived from the excessive treatment of the water during the first half of the daily period of raw water inflow is, however, greatly influenced by the fact that the settling basins are not baffled and that there are currents in the basins, which cause overtreated water to flow into the second settling basin and at times onto the filters, especially during the period when raw water alone is entering the south basin. The efficiency of the overtreatment is apparently intimately related to the degree of intermingling of the superlimed water and the neutralizing raw water which is subsequently admitted. Under Oberlin conditions, the poor distribution afforded at the point of entrance of the water into the first basin, and the fact that the six-hour period of raw water inflow may by displacement cause overtreated water to pass through the system, prevents a thorough mixing of the overtreated and the raw water, and thus in part defeats the beneficial effects which are possible by this method of applying the softening chemicals.

The actual quantity of chemicals applied does not vary widely as the impounded supply affords sufficient water for 75 days. During this investigation the actual quantity of lime and soda ash used have ranged from 6.4 to 15.1 and 2.4 to 6.7 grains per gallons, respectively, or 0.45 to 1.08 and 0.16 to 0.49 ton per million gallons, respectively, and is usually less in the summer seasons.

Water softening at Oberlin decidedly improves the physical character of the water, removes a certain percentage of the dissolved color and most of the vegetable organisms, but does not remove tastes and odors derived from algal decay. Decided odors and tastes were noticed in the softened water in the summer of 1906, but were less pronounced in the summer of 1907, a condition which is perhaps largely attributable to the new outtake whereby water is drawn from the reservoir from a point near the surface and not from the bottom as was formerly the case.

The degree of softening effected has been such as to afford a water comparable in hardness to that of the large cities on the Atlantic coast. The total hardness has ranged from 66 to 82 parts per million and the reduction in the several hardness constituents has been such that no difficulties have been experienced in the use of the water for manufacturing purposes. Ordinarily, the magnesium present in the raw water to the extent of from 10 to 55 parts per million has been reduced to from 3 to 16 parts per million without especial difficulty and without the occurrence of caustic alkalinity in the softened water especially attributable to an attempt to effect a large reduction in magnesium by the use of especially large quantities of lime.

Residual caustic alkalinity was found in the softened water on three of the four detailed examinations, and it was developed that the presence of unused lime is generally to be expected during cold weather, unless precautions are taken to destroy the excess of caustic by the use of copperas. This chemical as a substitute for recarbonating processes was first used at Oberlin in the winter and spring of 1906 and 1907. During the fall of 1907, it has again been employed to the extent of 2 grains per gallon. Indications are strong that the copperas tends to have a marked effect in reducing residual caustic alkalinity although conditions at Oberlin as to irregularities in displacement in the settling basin and as to the possibility that during the period when raw water is alone applied, superlimed water will flow into the second basin and thence to the filter with a too short period of reaction, prevents there being made definite general statements as to the efficacy on a practical basis of the use of copperas for this purpose. Furthermore, when copperas is used, the precipitated iron hydrate passes on to the filters, more rapidly clogs the sand, necessitates more frequent wash-

ing, increases the percentage of wash water required and increases the cost of the treatment even beyond that occasioned by the actual cost of the copperas itself.

In relation to residual caustic alkalinity evidence available for this special investigation has furnished suggestive data regarding the limitations of water softening during cold weather, especially when the temperature of the water is at or near that of the maximum density of water. At such times the softening action is greatly retarded. Evidence is strong that the somewhat long period of sedimentation possible at Oberlin is of special significance with respect to the efficiency of the softening during winter weather, especially relative to a softened water which shows a well balanced softening without objectionable large quantities of non-reacting lime. A comparison of the rapidity of the softening during summer and winter conditions, is especially instructive as regards the progressive softening effected as the water flows successfully through the basins, filters and into the service mains.

General evidence as to the tendency of the treated water to form deposits is to the effect that but little trouble has been experienced as regards service mains and faucets, but that certain types of meters have required some attention owing to deposits from the softened water. Although at times, there has been a small quantity of residual caustic alkalinity, yet it appears that this has not been sufficient to cause serious trouble and has had practically no effect upon the successful use of fish aquaria.

In the removal of bacteria from the raw water, the water softening process at Oberlin has sufficed to produce a water which contains exceptionally small numbers of bacteria. Of special significance is the high bacterial removal which results obtained during this investigation, indicate to be possible merely by the application of softening chemicals followed by a period of subsidence sufficient to remove the greater part of the precipitates. The settling basins alone have afforded a remarkably high bacterial removal and it is highly probable that this removal is due in a large part to the availability of magnesium which serves as a natural coagulant with high entraining power under the application of lime and the formation of the gelatinous magnesium hydrate. It is possible that the feature of overtreatment tends toward the rapid formation of a magnesium floc which in itself plays an important part in the large removal of bacteria afforded by the first basin alone. The bacterial efficiency of the settling basins, moreover, is so great that the filters are called upon to perform very little service. In view of the clogged condition of the filters during a greater part of this investigation it is probable that they are not especially efficient in removing bacteria.

The usually low bacterial content of the water of Oberlin as supplied, together with the almost complete absence of typhoid in the village suggest that the efficiency of the softening process is such as to afford a safe and wholesome water. It is, of course, to be noted that the raw water itself is rarely contaminated by sewage and that the primary purpose of water purification at Oberlin is a reduction in hardness, that the quality of the water may be improved with special reference to domestic uses and to soap consumption.

In closing this report of water softening at Oberlin and the results obtained during the special investigation of the State Board of Health, it is fitting to mention that the officials of the water board and of the water works have heartily co-operated with the Board and have rendered great assistance in carrying out the examinations of the plant.

COSTS.

The total cost of installation of the water softening features at Oberlin was **$15,154.**

Total Maintenance Expenses.

The total cost of maintenance of the Oberlin water works for the year 1907, compiled from the report of the superintendent, is shown in the following tables. These costs include all expenses incurred in the management of the water works.

Labor		$3,085
Salary of superintendent	$1,200	
One day engineer, at $70 per mo	840	
One night engineer, at $30 per mo	360	
One filter attendant, at $40 per mo	480	
Extra labor, cleaning basins, filters, etc	205	
Total	$3,085	
Chemicals		$721
Lime	$458	
Soda ash	263	
Total	$721	
Fuel 266 long tons at $3.50		$931
Extensions, Services, Supplies, Repairs, etc		$4,477
Extensions	$1,075	
Gas	47	
Meters	1,259	
Office expenses	109	
Oil and packing	59	
Rebates	28	
Repairs and supplies (distribution system)	615	
Repairs at pumping station	316	
Services	780	
Repairs at station residence	189	
Total	$4,477	
Interest, Taxes, Insurance		$2,432
Interest on bonds	$2,303	
Taxes, ($9.68)	10	
Treasurer's commission	52	
Insurance	67	
Total	$2,432	
Grand total		$11,646

The total pumpage for the year 1907, less the estimated volume of lime water was 70,586,000 gallons. The cost of furnishing water based upon the total operating expenses was $121 per million gallons. This cost is itemized as follows:

TABLE NO. 11.

Cost of Maintenance Per Million Gallons.

Labor	$43 80
Chemicals	10 20
Fuel	13 20
Miscellaneous and distribution system	19 33
Interest	34 40
Total	$120 93

The following table shows the actual cost of softening the water exclusive of items chargeable to the maintenance of the water works alone. Included in this cost is the labor of one filter attendant and also that incidental to the cleaning of the basins and filters, chemicals and interest charges on the bond issue for the construction of the water softening devices installed in 1903.

TABLE NO. 12.

Cost of Water Softening for the Year 1907.

Cost of chemicals	$721
Labor, filter attendant	480
Labor, extra	205
Interest charges	543
Total	$1,949

The total gallons softened in 1907 was 70,586,000. The total cost of softening per million gallons is, therefore, $27.60, itemized as follows:

Lime	$6.50
Soda ash	3.70
Labor	9.70
Interest	7.70
Total	$27.60

The actual cost of operation of the pressure filters is very small and ordinarily includes only the cost of wash water. During 1907, however, extensive repairs were made to the filters as already noted. The cost of these changes is included under the item "Repairs at pumping station."

SANITARY ANALYSES OF RAW AND SOFTENED WATER, AUGUST 24, 1906.

	Parts Per Million.	
	Raw Water.*	Tap at Fountain, Public Square.
Color	35	10
Turbidity	20	5
Sediment	decided	trace
Oxygen Consumed	5.56	3.28
Nitrogen as		
Albuminoid Ammonia	0.234	0.012
Free Ammonia	0.058	0.006
Nitrites	0.006	.....
Nitrates	0.00	.....
Chlorine	14.0	12.8
Alkalinity	152	48
Incrustants	70	27
Total Solids	422	280
Loss on Ignition	110	60
Iron	0.3	0.2
Bacteria per c.c.	500	35
B. Coli.	Not in 100 c.c.	Not in 100 c.c.

* Composite half-hourly 7:00 A. — 5:00 P.

BIOLOGICAL ANALYSIS.

A composite sample of the raw water collected on August 24, 1906, was examined in the laboratory for microscopic organisms with result as follows:

The total number of organisms ranged from 10,000 to 15,000 and showed a great variety of species among which the following were most prominent:

Diatomaceae	Naviculeae.
Protozoa	Euglena,
	Cratium,
	Stentor,
	Uroglena,
	Vorticella,
	Cyclops,
	Amoeba.
Chlorophyceae	Desmids.
Schizomycetes	Various yeast cells,
	Fragments of spirogyra.
Rotifera	Anuraea cochlearis.
Plankton	Fragments of vegetable organisms,
	Sponge spicules, etc.

Samples of the filtered water were examined at the same time and were found to be practically free from organisms, although some of the samples contained fragments of a brown algae, some diatoms and a few sponge spicules with a total count of about 50 per cubic centimeter. It was concluded that although the filtered water contained but few organisms, and none that would account for the taste of the water, yet the result of the decomposition of the very abundant life in the raw water would be sufficient to explain almost any unpleasantness.

TABLE NO. 13.

Chemical and Bacterial Analyses.

Source.	Date 1906-07.	Hour.	Temperature Deg. F.	Parts per Million.									Bacteria per cubic centimeter.
				Alkalinity.				Total Hardness.	Magnesium.	Color.	Turbidity.	Iron.	
				Phenol ($CaCO_3$)	Caustic (CaO)	Total ($CaCO_3$)	Incrustants.						
Raw water	August 23, 1906....	7:00 A.	.....	.....	0	176	70	246	20	32	.....	.....	.....
" "	" 23, 1906....	9:00 A.	.....	5	0	180	70	250	19	31	.....	.....	.....
" "	" 23, 1906....	11:00 A.	.....	6	0	188	70	258	19	35	.....	.....	300
" "	" 23, 1906....	1:00 P.	.....	4	0	184	70	254	27	40	.....	.....	.....
" "	" 23, 1906....	3:00 P.	.....	6	0	172	70	242	23	35	.....	.....	500
" "	" 23, 1906....	5:00 P.	.....	7	0	180	70	250	23	38	.....	.....	400
Average	.....		.....	6	0	180	70	250	22	35	.....	.....	400
1st Basin	" 23, 1906....	7:00 A.	.....	.....	....	82	11	93	.....	18	.....	.....	.....
" "	" 23, 1906....	3:00 P.	.....	.....	....	93	12	105	.....	18	.....	.....	45
Average	.....	.....	.....	.....	....	88	12	99	.....	18	.....	.....	45
2nd Basin	" 23, 1906....	7:00 A.	.....	.....	....	73	24	97	.....	10	.....	.....	.....
" "	" 23, 1906....	3:00 P.	.....	.....	....	77	28	105	.....	13	.....	.....	.....
Average	.....	.....	.....	.....	....	75	26	101	.....	12	.....	.....	.....

TABLE NO. 13 — Continued.

Source.	Date 1906-'07.	Hour.	Temperature Deg. F.	Parts Per Million.									Bacteria per cubic centimeter.
				Alkalinity.			Incrustants.	Total Hardness.	Magnesium.	Color.	Turbidity.	Iron.	
				Phenol ($CaCO_3$)	Caustic (CaO).	Total ($CaCO_3$)							
Filters	August 23, 1906	7:00 A.	.....	.....	....	44	12	56	.....	10	.....	.....	30
"	" 23, 1906	3:00 P.	.....	.....	....	52	36	88	.....	10	.....	.....	.....
Average	.....	.....	.....	.....	....	48	24	72	.....	10	.....	.....	30
Public fountain	" 23, 1906	8:30 A.	.....	.....	....	44	10	54	.....	15	.....	.....	35
" "	" 23, 1906	2:00 P.	.....	.....	....	49	30	79	.....	12	.....	.....	.....
Green house	" 23, 1906	9:00 A.	.....	.....	....	35	.....	.....	.....	14	.....	.....	50
Average	.....	.....	.....	.....	....	43	35	78	.....	14	.....	.....	43
Raw water	Sept. 11, 1906	9:00 A.	.....	0	0	160	80	240	10	.....	.....	.....	.....
1st Basin	" 11, 1906	9:00 A.	.....	13	0	99	47	146	9	.....	.....	.....	.....
2nd Basin	" 11, 1906	9:00 A.	.....	31	0	75	25	100	6	.....	.....	.....	.....
Filters	" 11, 1906	9:00 A.	.....	22	0	59	24	83	7	.....	.....	.....	.....
Public fountain	" 11, 1906	9:00 A.	.....	18	0	41	15	56	5	.....	.....	.....	.....
Green house	" 11, 1906	9:00 A.	.....	10	0	45	0	45	3	.....	.....	.....	.....
Average	.....	.....	.....	14	0	43	8	51	4	.....	.....	.....	.....
Raw water	January 16, 1907	8:30 A.	.....	*5	0	146	87	233	36	30	.....	.....	650
" "	" 16, 1907	11:00 A.	.....	*5	0	154	90	244	45	40	.....	.....	500
" "	" 16, 1907	2:00 P.	.....	*5	0	150	90	240	38	40	.....	.....	800

" "	"	16, 1907...	5:00 P.	.....	*6	0	144	85	229	31	40	.....	.....	690
" "	"	17, 1907...	7:00 A.	.....	*4	0	144	85	229	14	40	.....	.....	1050
Average	.....	.....	.....	.....	5	0	148	87	235	33	38	.....	.....	738
1st Basin	"	16, 1907...	8:30 A.	.....	81	26	116	50	166	16	10	.....	.....	6
" "	"	16, 1907...	11:00 A.	.....	82	26	117	50	167	24	<5	.....	.....	7
" "	"	16, 1907	2:00 P.	.....	92	29	133	55	188	25	<5	.....	.....	14
" "	"	16, 1907	5:00 P.	.....	84	22	128	52	180	4	12	.....	.....	6
" "	"	17, 1907	7:00 A.	.....	87	34	113	48	161	5	5	.....	.....	9
Average	.....	.....	.....	.....	85	27	121	51	172	15	7	.....	.....	8
2nd Basin	"	16, 1907...	8:30 A.	.....	45	3	84	30	114	20	15	.....	.....	36
" "	"	16, 1907...	11:00 A.	.....	31	0	96	32	128	31	20	.....	.....	100
" "	"	16, 1907...	2:00 P.	.....	35	0	84	30	114	19	15	.....	.....	25
" "	"	16, 1907...	5:00 P.	.....	51	7	90	32	122	9	12	.....	.....	45
" "	"	17, 1907...	7:00 A.	.....	50	6	90	32	122	10	15	.....	.....	21
Average	.....	.....	.....	.....	42	3	89	31	120	18	15	.....	.....	57
Filters	"	16, 1907...	8:30 A.	.....	38	8	78	27	105	15	10	.....	.....	10
"	"	16, 1907...	11:00 A.	.....	37	2	70	25	95	27	12	.....	.....	21
"	"	16, 1907...	2:00 P.	.....	29	0	73	45	118	18	15	.....	.....	16
"	"	16, 1907...	5:00 P.	.....	47	13	71	25	96	12	10	.....	.....	5
"	"	17, 1907...	7:00 A.	.....	56	20	76	26	102	11	10	.....	.....	13
"	"	17, 1907...	8:45 A.	.....	46	6	82	30	112	12	15	.....	.....	.....
"	"	17, 1907...	9:15 A.	.....	52	18	72	26	98	13	10	.....	.....	.....
Average	.....	.....	.....	.....	44	8	75	29	104	15	12	.....	.....	13
Public fountain	"	16, 1907...	8:30 A.	.....	29	0	59	18	77	19	15	.....	.....	10
" "	"	16, 1907...	2:00 P.	.....	38	6	66	18	84	19	12	.....	.....	9
" "	"	17, 1907...	2:15 P.	.....	43	10	68	13	81	14	10	.....	.....	9
Green house	"	16, 1907...	8:30 A.	.....	26	0	54	0	54	29	10	.....	.....	6
Park hotel	"	16, 1907...	2:00 P.	.....	41	4	74	27	101	10	15	.....	.....	7
Res. W. B. Gerrish	"	17, 1907...	1:30 P.	.....	40	12	58	6	64	12	10	.....	.....	.....
Children's Home	"	17, 1907...	1:38 P.	.....	29	1	56	0	56	14	10	.....	.....	13

TABLE NO. 18 — Continued.

Source.	Date 1906-'07.	Hour.	Temperature Deg. F.	Parts Per Million.									
				Alkalinity.			Incrustants.	Total Hardness.	Magnesium.	Color.	Turbidity.	Iron.	Bacteria per cubic centimeter.
				Phenol ($CaCO_3$)	Caustic. CaC)	Total ($CaCO_3$)							
Prospect St. School	January 17, 1907	2:07 P.	.....	44	13	64	12	76	14	15	.....	.....	11
College Laboratory	" 17, 1907	2:25 P.	.....	37	5	65	10	75	15	10	.....	.....	.....
Average	.....	.....	.....	36	6	63	10	74	16	12	.....	.....	7
Raw water	March 18, 1907	7:30 A. 3:30 P.	42	*6	0	150	95	245	24	55	20	0.5	.....
" "	" 19, 1907	7:00 A. 2:00 P.	41	*7	0	142	90	232	23	55	20	0.3	.....
Average	.....	.....	.....	42	7	0	146	93	239	24	55	20	0.4	.....
1st Basin	" 18, 1907	7:30 A.	42	42	8	69	44	113	22	6	5	0.2	.....
" "	" 18, 1907	10:00 A.	43	52	11	84	26	110	39	6	20	0.1	39
" "	" 18, 1907	1:00 P.	43	104	45	128	28	156	18	6	25	0.6	72
" "	" 18, 1907	3:30 P.	43	84	26	122	42	164	11	10	25	0.5	.....
" "	" 19, 1907	7:00 A.	42	56	18	80	48	128	10	10	20	0.3	.....
" "	" 19, 1907	11:00 A.	42	96	38	124	20	144	6	10	20	0.2	.....
Average	.....	.....	.....	43	72	24	101	35	136	18	8	19	0.3	55

2nd Basin	" 18, 1907	7:30 A.	43	59	18	85	22	107	21	30	5	0.2	.....
" "	" 18, 1907	10:00 A.	43	68	27	88	27	115	20	30	5	0.3	23
" "	" 18, 1907	1:00 P.	44	36	0	72	26	98	18	30	5	0.3	29
" "	" 18, 1907	3:30 P.	45	48	9	80	45	125	17	32	5	0.4	.....
" "	" 19, 1907	7:00 A.	43	54	15	82	40	122	17	15	5	0.2	.....
" "	" 19, 1907	11:00 A.	42	64	20	92	40	132	17	10	5	0.1	.....
Average			43	55	15	83	33	116	18	25	5	0.3	9
Filters	" 18, 1907	7:30 A.	43	38	9	60	32	92	13	20	<5	0.1	.....
"	" 18, 1907	10:00 A.	43	40	10	62	32	94	10	20	<5	0.1	8
"	" 18, 1907	1:00 P.	44	36	9	56	36	92	11	10	<5	0.1	0
"	" 18, 1907	3:30 P.	43	36	10	54	30	84	11	20	<5	0.1	.....
"	" 19, 1907	6:00 A.	45	32	6	54	46	100	16	15	<5	.....	.....
"	" 19, 1907	7:00 A.	45	32	3	58	66	124	10	15	<5	0.1	.....
"	" 19, 1907	11:00 A.	43	38	12	54	51	105	12	15	<5	.....	.....
Average			44	36	8	57	42	99	12	16	<5	0.1	4
Public fountain	" 18, 1907	11:30 A.	44	34	8	54	26	80	12	15	<5	.....	.....
" "	" 19, 1907	10:36 A.	45	34	9	52	43	95	12	15	<5	.....	32
Res. W. B. Gerrish	" 19, 1907	10:05 A.	41	32	9	48	3	51	8	10	<5	0.1	4
Children's Home	" 19, 1907	10:20 A.	41	30	8	46	36	82	9	10	<5	.....	8
Green House	" 19, 1907	10:40 A.	43	32	9	48	29	77	11	15	<5	.....	3
Gas Works	" 19, 1907	11:03 A.	46	34	11	48	45	93	11	15	<5	.....	14
School house	" 19, 1907	11:20 A.	41	34	11	48	38	86	17	15	<5	.....	18
Average			43	33	9	49	31	80	11	14	<5	0.1	11
Raw water	August 20, 1907	7:00 A.											
		2:00 P.	73	0	0	176	95	271	32	10	.....	0	250
1st Basin	" 20, 1907	2:00 P.	73	53	13	82	26	108	11	0	.....	0	16
" "	" 21, 1907	8:00 A.	72	41	0	84	39	123	18	5	.....	.....	3
" "	" 21, 1907	11:00 A.	70	73	27	98	32	130	18	5	.....	.....	14
" "	" 21, 1907	3:30 P.	69	34	6	78	51	129	15	0	.....	.....	17
Average			71	50	12	86	37	123	16	3	.....	0	13

TABLE NO. 13 — Concluded.

Source.	Date 1906-07.	Hour.	Temperature Deg. F.	Parts Per Million.									Bacteria per cubic centimeter.
				Alkalinity.			Incrustants.	Total Hardness.	Magnesium.	Color.	Turbidity.	Iron.	
				Phenol ($CaCO_3$)	Caustic (CaO)	Total ($CaCO_3$)							
2nd Basin	August 20, 1907...	2:00 P.	72	30	1	61	30	91	15	0	.....	.....	17
" "	" 21, 1907....	8:00 A.	70	28	0	59	46	105	14	5	.....	.....	7
" "	" 21, 1907....	11:00 A.	71	34	3	62	37	99	20	0	.....	.....	32
" "	" 21, 1907....	3:30 P.	70	36	7	60	47	107	12	0	.....	.....	8
Average	.....	.....	71	32	3	61	40	101	15	1	.....	.....	16
Filters	" 20, 1907....	2:00 P.	73	18	0	38	32	70	11	5	.....	.....	11
"	" 21, 1907....	8:00 A.	70	30	8	45	41	86	8	5	.....	.....	2
"	" 21, 1907....	11:00 A.	71	35	6	60	45	105	13	0	.....	.....	24
"	" 21, 1907....	3:30 P.	70	30	8	45	39	84	8	0	.....	.....	4
Average	.....	.....	71	28	6	47	39	86	10	3	.....	.....	10
Public fountain	" 20, 1907....	3:00 P.	70	21	0	43	34	77	8	5	.....	0	3
" "	" 21, 1907....	3:10 P.	60	21	2	38	36	74	9	5	.....	0.1	3
Green house	" 21, 1907....	3:05 P.	57	18	1	35	35	70	9	5	.....	0	3
Children's Home	" 21, 1907....	2:45 P.	61	18	1	35	42	77	12	0	.....	0	2
Res. W. B. Gerrish	" 21, 1907....	2:55 P.	61	21	3	36	30	66	10	5	.....	0	3
Res. Prospect St.	" 21, 1907....	3:25 P.	61	24	5	39	37	76	8	5	.....	0	4
Average	.....	.....	62	21	2	38	36	74	9	6	.....	0	3

* Alkaline to Phenolphthalein.

Report on Examination of Sewage Purification Plants

AND

Supplementary Reports on (1) Disinfection of Sewage Effluents and (2) Purification of Acid Iron Wastes at Shelby.

BY

A. ELLIOTT KIMBERLY,

Special Assistant Engineer.

REPORT ON EXAMINATION OF SEWAGE PURIFICATION PLANTS.

INTRODUCTION.

This report contains a detailed description of thirty-eight of the sewage purification plants in Ohio, together with a discussion of operation, efficiency and costs as developed during the special investigation of the State Board of Health.

There are first described the general methods of conducting field tests and the apparatus and equipment used, following which each plant is considered separately under these heads:

1. GENERAL FEATURES RELATING TO CITY, VILLAGE, OR INSTITUTION.
2. SEWERAGE.
3. CONDITIONS LEADING TO SEWAGE PURIFICATION.
4. EXAMINATIONS AND INSPECTIONS.
5. DESCRIPTION OF PLANT.
6. SEWAGE FLOW.
7. COMPOSITION OF CRUDE SEWAGE.
8. OPERATION.
9. EFFICIENCY.
10. COSTS.
11. DETAILED ANALYTICAL DATA.

The report concludes with a comparative summary in which it is purposed to present in terse form the results of the investigation, with relation to the general problem of sewage purification and its application under Ohio conditions.

CONDUCT OF FIELD TESTS.

For twenty months, from April, 1906, to December, 1907, there were made a number of short visits to each of the sewage purification plants in the state for the purpose of obtaining information as to their efficiency. These visits were of two classes, and are spoken of as "detailed examinations" and "inspections," respectively. On detailed examinations, there was made a special study of the general features of operation for a period of from one to two days, together with a collection of such analytical data as are necessary to determine the results obtained by a sewage purification plant. As the investigation progressed, it was developed that a careful inspection of features of operation alone would at times give sufficient information regarding the efficiency of a sewage purification plant, especially after at least one thorough detailed examination. In many instances, therefore, inspections alone were made.

On each visit, informal advice was given relative to methods of operation or features of construction and after a careful study of information available from the detailed examination, in a number of instances suggestive changes were recommended formally by a letter from the secretary of the Board. The information obtained on detailed examinations was further supplemented by daily records of features of operation. These records were kept at a number of plants for about 12 to 15 months during the investigation.

METHODS OF STUDY OF OPERATING FEATURES AND NATURE OF GENERAL INFORMATION COLLECTED.

On all detailed examinations, information was obtained as to features of operation especially pertinent to each plant. The desired data, of course, varied according to the type of plant under study, but in general the following may be said to embrace the principal points relative to which information was obtained.

Measurements of sewage flow, measurements of scum and sludge, methods of operation, capacity and periods of flow of preparatory devices, quantity of, rates of application and strength of solutions of applied chemicals, composition of the dry chemical, volume of dose of sewage, precision of operation of automatic devices, raking, scraping and removal of material, details of construction of the plant, and observations of the temperature of the air and of the sewage at different points.

For compiling a complete report of these plants, during this investigation information was obtained as to the population, sewerage system, street improvements, principal industries of the city or village and similar information in the case of institutions. An effort was made to obtain as complete cost data as possible, both as to installation and operating expenses.

Measurements of Sewage Flow. Gagings of the sewage flow at the different plants were made by the ordinary methods of weir measurement. It was generally necessary to construct temporary weirs for this purpose, although in a few cases facilities for gaging the flow of sewage were provided when the plant was built. Weirs were constructed in manholes, channels and other places where measurements could conveniently be made. In certain of the smaller plants, it was not practicable to weir the sewage flow, especially where dosing tanks were used, and in these cases it was customary to keep a record of the number of discharges of the dosing tank. In some places, the flow of sewage was determined by observations of the rate of pumping and in others, especially in institutions, the rate of sewage flow was determined from the daily water consumption which could usually be learned with sufficient accuracy.

Practically all of the detailed examinations lasted at least 24 hours, and it was the general practice to continue measurements of the sewage flow during the entire period of a test. Measurements were usually made at half hourly intervals.

During this investigation no special effort was made to obtain data as to the volume of sewage flow at different points in a sewerage system, nor were there any special measurements of the ground water leakage except as indicated by the high sewage flow during the night hours. These data are valuable, but were perhaps somewhat beyond the scope of this work, although in future studies along this line such measurements could probably be made with profit in some instances.

Measurements of Sludge. Measurements of the sludge deposits in settling and septic tanks were made by means of a pole. Observations were made at different points in the tank. These measurements while rough afforded information of sufficient accuracy for the purpose of this investigation. It is, of course, a somewhat difficult matter to measure accurately the depth of sludge in settling tanks whilst they are in operation. In the earlier detailed examinations, an effort was made to use the Fowler sludge tube. It was found, however, that the density of the sludge in most instances was so great as to prevent the upward flow of the deposit into the tube.

Daily Records. Blank forms were sent to a number of plants on which were to be recorded daily some of the most important features of operation. These blanks provided for recording daily the temperature of the air and of the sewage

at different points, average daily rates of sewage flow, as shown by weir measurements, a record of the hours of pumping or number of discharges of the dosing tanks, and in general data necessary to indicate the volume of sewage flow, the number of filters in service, records of cleaning, scraping and the removal of filtering material or sludge, together with observations of any other unusual features relative to the operation of the plant and in four instances, tests for putrescibility. Each blank was arranged for one month's use. Together with the blanks, there were sent return envelopes so that the records could be sent into the office at the end of each month.

Assistants Employed. In carrying out the detailed examinations of the larger plants, the special assistant engineer was assisted by the engineering assistant. To assist in the collection of samples and in making such observations as were continuously recorded during a field test, assistants were secured from the city, village or institution. In most instances, officials in charge of sewage plants have heartily co-operated with the Board in connection with the field work incidental to this investigation and its success is in large measure due to the courtesies and assistance so rendered, all of which are gratefully acknowledged.

Daily Putrescibility Tests by Operators of Plants. At four of the larger plants where coarse grain filters are in operation, the Board sent incubators for the daily determination of the putrescibility of the final effluent. These were 50-egg chicken incubators made by the Cyphers Incubator Company of Buffalo, New York. They proved to be very satisfactory and were, of course, much cheaper than the usual laboratory apparatus.

There were two incubation tests used during this investigation, the smell test and the chemical test. The smell test was merely the well known method of incubating a sample in a tightly stoppered bottle for 24 hours at 37 degrees Centigrade. The chemical test used is one developed at Tillburg Testing Station, Holland, and consists in incubating equal volumes of the effluent and well aerated tap or river water for a period of 24 hours. At the end of this period, the presence of residual dissolved oxygen is qualitatively determined by the addition of 0.5 cubic centimeter each of the usual dissolved oxygen reagents, manganous sulphate and alkaline potassium iodide. The oxygen introduced in this test is sufficient to complete the oxidation of the organic matter which remains in a non-putrescible effluent, but in case the effluent is unstable, the combined action of bacteria and organic matter completely exhaust the oxygen during the incubation period and in this case, therefore, an unsatisfactory effluent is indicated.

These tests proved very satisfactory for conditions which exist at the four plants where they were used. No special analytical studies were made as to the reliability of the tests but by referring to the discussion of the efficiency of the Lakewood sewage plant (See p. 501), it will be noted that with very few exceptions, there is practically an agreement between the results of the smell and chemical tests. In other words, samples which on incubation give off no objectionable odors, are sufficiently stable so that the oxygen introduced in the aerated tap water is not exhausted, a fact which is indicative of aerobic conditions in the mixed effluent and tap water during the period of incubation. This chemical test can easily be performed by the average operator who merely records on a prepared blank in the proper place plus or zero depending upon the development of a white precipitate, showing the entire absence of oxygen or a brown precipitate, showing residual oxygen, a satisfactory condition which is recorded as zero putrescibility.

COLLECTION OF SAMPLES.

One of the most important points in relation to the examinations of sewage purification plants, refers to the collection of samples of the sewage and effluents which are truly representative of average conditions during the period covered by the test. Chance samples convey but little information and deductions from the analysis of such samples cannot be considered reliable. In this investigation there was made a special effort to obtain average composite samples which would not only be representative of the sewage or effluent under examination for the total period covered by the examination, but would also be weighted to correspond to the fluctuating rate of flow of the sewage. In this investigation, therefore, *all analytical data, unless otherwise stated have been obtained from the analysis of average samples collected generally at half hourly intervals throughout a test. In the case of the crude sewage, the average samples are composites obtained by mixing together such portions of the half hourly samples as correspond to the rate of sewage flow at the time these half hourly samples were collected.* If the crude or septic sewage was applied to the filters in doses it was customary in the case of the crude sewage to take samples at equal and frequent intervals during the discharge of a dosing tank. These samples were mixed in equal portions to form a composite. But in most instances and whenever possible weir measurements were made and samples were collected individually and were mixed to form a weighted average composite. Effluent samples, however, have not been weighted, but as well, are averages which comprise equal portions collected at half hourly intervals.

Other samples collected during each examination were samples for dissolved oxygen. They were collected in the usual manner at 4-hour intervals throughout the period covered by an examination in the case of all the devices sampled. Reagents were added to the bottles immediately after the collection of samples. The temperature of the sewage and of the effluents and also of the air were observed at 4-hour intervals during each test.

Crude Sewage. Samples of the crude sewage were collected in 8-ounce sampling bottles at half hourly intervals and were labeled and placed on ice. The examinations usually began either at midnight or at 8:00 o'clock A. M., and in the case of crude sewage, the samples were collected for a period of 24 or 48 hours. The crude sewage samples were divided into day and night periods. Usually the night period was considered to be from 12:00 o'clock midnight to 8:00 o'clock A. M. and the day period from 8:00 o'clock A. M. to 12:00 o'clock midnight. In some cases this division of hours was not strictly followed in conformity with local conditions in the town or institution under study. At the end of a sampling period the individual samples in the 8-ounce bottles when well shaken were mixed in a 12-quart galvanized iron bucket in proportion to the sewage flow corresponding. It was the practice to use one or more cubic centimeters of the individual portions for each thousand gallons of sewage flow or such relation as the volume of sewage would warrant. It is evident that by this means there was obtained a composite sample which was truly representative of the crude sewage during the hours covered by the sampling with due regard to the effect of the changing rate of flow.

Effluents from Preparatory Processes. Sample of septic or settled sewage were similarly collected at half hourly intervals, but were mixed as collected in equal portions generally one-half pint each. The period of sampling was continued for 24 hours or longer and the sampling was not commenced until a length of time after there was begun the sampling of the crude sewage, as corresponded to the average period of flow of the settling or septic tank. On account of the well known mixing effect of settling and septic tanks, it was considered that

equal portions of the effluent collected at half hourly intervals for 24 hours would be sufficiently representative of the average effluent for that period. At times the effluents of the preparatory devices were collected to correspond to the influents of contact filters.

Effluents from Coarse Grain Filters. Effluents from contact filters were collected in equal portions at 10 or 15-minute intervals during a discharge and were mixed as collected. Usually, the sampling period was caused to conform to that covered by the preparatory devices. The composite samples of each discharge of each filter were mixed in equal portions for the period covered by the examination and were separately analyzed. In case of a 48-hour test, however, on the second day the average effluents from all of the contact filters were combined to form one composite sample.

Effluents from Fine Grain Filters. In the case of coarse grain filters operated continuously and also fine grain filters, samples were collected in equal portions at half hourly intervals usually for a period of 24 hours, and were mixed as collected. In some instances on account of dosing features, the period of sampling was shorter. The general plan followed in sampling the effluents at a given plant was to arrange the period covered to correspond to the sampling schedule for the crude sewage and the effluents of the preparatory treatment.

FIELD AND LABORATORY ANALYSES.

A complete analysis comprised the following determinations: Oxygen consumed, nitrogen as organic matter, free ammonia, nitrites and nitrates, chlorine, total and volatile suspended matter, fats, putrescibility and dissolved oxygen. Of these determinations, oxygen consumed, nitrogen as free ammonia, nitrites and nitrates, chlorine, dissolved oxygen and putrescibility regularly formed a part of the field work. The remaining constituents were determined on chloroformed samples expressed to the laboratory of the Board. These field determinations were carried out whenever possible, but at times owing to lack of heating facilities the oxygen consumed tests were omitted and were made by the laboratory. It is evident that the tests performed in the field include all those constituents subject to change and hence in error in case samples had been shipped to a central laboratory for analysis.

The analysis of samples collected on a given test were carried out as soon as possible after its completion. Some of the determinations, especially dissolved oxygen were made at the plant, but in case of the majority of the determinations, the work was usually performed in some building nearby where water and gas were available. The equipment carried in this work was such as to allow all of the field analytical work to be completed without unusual difficulty.

The methods employed in the work in general terms corresponded to the requirements of the Committee on Standard Methods of the American Public Health Association. There were, however, a few exceptions necessitated by the exigencies of field work as follows:

Nitrogen as Free Ammonia. There was employed a method of direct nesslerization which conformed practically to that used at Columbus (1). It comprised merely the addition to about 100 cubic centimeters of the sewage or effluent of 1 cubic centimeter of 50 per cent. caustic soda. In case the sample contained relatively little magnesium, it was customary to add first 1 cubic centimeter of a 10 per cent. solution of magnesium chloride. Ordinarily without this chemical, there was soon formed a flocculent precipitate which entrained the organic and suspended matters and after about 30 minutes left a clear supernatant

[1] Johnson, Report on Sewage Purification, Columbus, Ohio, p. 46.

liquid in which the ammonia could be read by direct nesslerization with practically no difficulty due to turbid tubes. In this connection it is to be remarked, that the hard waters in Ohio at times interfere with the nesslerization process and in washing the nessler tubes, it is necessary to finish with a double rinse in distilled water, and also to subject the tubes to an occasional bath of chromic acid cleaning mixture.

Nitrogen as Nitrates. The phenol di-sulphonic acid method was used.

Putrescibility Tests. For putrescibility, samples of the average effluent were collected in stoppered bottles and were shipped to the laboratory for incubation. In most of the plants, where such tests are of importance incubation facilities were readily obtainable. It was, of course, possible to determine merely by inspection that the effluents from the fine grain filters were usually stable so that actual tests for putrescibility were not necessary.

SAMPLING OUTFIT.

For the collection of samples of crude and at times for partially treated sewage, there were used 8-ounce square wide-mouthed bottles provided with closely fitting cork stoppers. These bottles were shipped from place to place in a substantial wooden box with protection against breakage by means of excelsior, hay or straw.

Other requisites of the field outfit exclusive of glassware, comprised the following:

2 6-inch tin funnels.
2 Tirrel Burners and rubber tubing.
4 ½-pint tin measures.
1 ¼-inch brass Y.
2 thermometers.
1 iron ring stand with two rings.
1 dozen 12-quart galvanized buckets.
Copper wire.
Wire cutters.
1 Chaddock burette stand.
Filter paper.
50 feet of rope.
1 suit of oil skins.
Labels.

The heavier items just listed were shipped in a small padlocked box, known as a "burner box" and the other equipment was packed with the 8-ounce sampling bottles, with exception of the burette stand and the iron buckets. The former was shipped with the glassware and the latter in a special crate.

The glassware exclusive of the chemicals was shipped in a 26-inch leather dress suit case. The case contained the following articles:

36, 50 c. c. Nessler tubes.
12, 100 c. c. nitrite or iron tubes.
2 round bottom 300 c. c. flasks.
1, 250 c. c. Erlenmeyer flask.
1, 25 c. c. graduated cylinder.
1, 100 c. c. graduated cylinder.
1, 500 c. c. graduated cylinder.
3 nested wooden racks for Nessler and nitrite tubes.
1, 4-inch glass funnel.
1 Chaddock burette stand.

The Nessler tubes and the nitrite tubes were placed into heavy felt cases holding twelve and six tubes, respectively. These cases afforded fairly satisfactory protection against breakage, provided due care was exercised in packing the suit case. Other glassware in the case were protected by wrapping with flannel.

For the collection of samples of dissolved oxygen two dozen calibrated bottles were also provided and were shipped in a separate box. As occasion warranted, 1-quart glass stoppered tincture bottles were shipped from the laboratory in containers holding 4 one-quart bottles each and in these there were placed the chloroformed samples for shipment to the laboratory.

CHEMICAL KIT.

Reagents used in the field analytical work were shipped in a chemical kit of special construction. This box contained twenty-four 8-ounce glass stoppered tincture bottles. The dimensions of the box were as follows: 13 inches x 2 feet 6½ inches in plan and 10 inches deep, with hinged tightly fitting cover. The cover was 2¾ inches deep and was arranged as a trunk cover so that the actual depth of the case was 7¼ inches.

Each reagent bottle was held firmly in a circular compartment lined with ⅜-inch harness felt. A similar lining covered the inside of the cover. Each bottle rested on an individual false wooden bottom which in turn rested on a brass spring which allowed a play of about ⅛ inch. By this means, all vertical and lateral motion was prevented and when closed, the felt cover and the false bottom with spring attachment held the bottles rigidly in place. Experience with this box soon developed that there was practically no danger of breakage although on account of the impracticability of obtaining accurately fitting glass stoppers, there was some leakage especially in the case of some of the heavier chemicals. It was then decided to paraffin the stoppers after each test. The reagent bottles thus protected could be shipped from place to place with practically no breakage and in general this method of shipping reagents proved very satisfactory.

The following is a list of reagents for field use as carried during this investigation. For convenience they are listed under the heads of the different determinations made.

LIST OF REAGENTS FOR FIELD USE.

REAGENT.	NUMBER OF BOTTLES.
Nitrogen as Free Ammonia.	
Ammonia standard	1
Magnesium chloride 10%	1
Nessler reagent	1
50% caustic soda	1
Nitrogen as Nitrites.	
Sulphanilic acid	2
Naphthylamine	2
Nitrite standard	1
Nitrogen as Nitrates.	
Nitrate standard	1
Phenol di-sulphonic acid	1
Oxygen Consumed.	
Standard potassium permanganate	2
Standard ammonium oxalate	1
1:1 sulphuric acid	1

REAGENT.	NUMBER OF BOTTLES.
Chlorine.	
Standard silver nitrate	1
Potassium chromate	1
Free Carbonic Acid.	
N/22 Sodium carbonate	1
Phenolphthalein	1
Dissolved Oxygen.	
Manganous sulphate saturated solution	1
Potassium iodide in caustic potash	1
Starch	1
Chloroform	1
Standard sodium thiosulphate	1
Total	24

ARRANGEMENT OF DETAILED REPORTS.

In addition to the general statements already made it is of interest to consider briefly the detailed methods of describing each plant and of discussing the results obtained.

In the report on municipal plants there are described in turn the several devices by which the sewage is treated in its flow through the plant. So far as possible, the different plants are described under similar headings and it has been the desire to make the description sufficiently complete so as to embrace the most important points which are reflected in the design.

In the case of institutional plants, a description of the dosing tank is placed under a separate head, rather than under the discussion of the filters and means for flooding as is the case in the larger plants where no dosing tanks are provided.

Sewage flow data are presented with reference to both the several detailed examinations made at each plant and daily records, in case such are available. In a number of instances in the more important plants the hourly sewage flow is presented on the basis of the percentage of the average flow for a 24-hour period.

The composition of the crude sewage is reviewed chiefly with respect to its general character and except in a few cases, for details as to the analytical character of the sewage, reference should be made to the analytical data which are presented at the close of the report on each plant.

The discussion of operating features follows the general course of the sewage through the plant. This section of the report treats of all ordinary operating features together with all similar information brought out by the investigation.

In a similar manner, the efficiency of the plant has been reviewed with reference to the results of detailed examinations, inspections and daily records. The discussion relates to all phases of the treatment of the sewage from the preliminary screening to the final treatment on the finishing devices. Concluding the subject of efficiency, there is a brief summary in which are reviewed the general results obtained by the plant during this investigation.

The report on each plant is concluded by a presentation of available cost data both as to installation and operating expenses. It has not been possible in all cases to obtain full information relative to the former costs, but usually total estimates are available. In some instances there have been obtained very complete ordinary and extraordinary expenses for the years 1906 and 1907. These cost data have been itemized under several headings whenever possible and are also expressed in terms of annual costs per capita.

For convenient reference, the detailed reports of the sewage purification plants

are arranged alphabetically under the two heads of municipal and institutional plants and hence this section of the report is separated into two parts.

The sewage plants in operation in Ohio embrace a wide range of processes in which all the better known methods of sewage treatment are represented. With respect to the type of process employed, the municipal and the institutional plants of Ohio may be grouped as follows:

MUNICIPAL PLANTS

Chemical Precipitation Only.

Alliance.
Canton.

Natural Soil or Artificial Sand Filters Without Preparatory Treatment.

Clyde.
Fostoria.

Natural Soil or Artificial Sand Filters With Preparatory Treatment by Chemical Precipitation.

Glenville.
Oberlin.

Natural Soil or Artificial Sand Filters With Preparatory Treatment in Settling or Septic Tanks.

Ashland.
Geneva.
Shelby,
Xenia.

Contact Filters With Preparatory Treatment in Settling or Septic Tanks.

Delaware.
Lakewood.
London.
Mansfield.
Marion.
Plain City.
Westerville.

Continuous Filters With Preparatory Treatment in Settling or Septic Tanks.

East Cleveland.
Kenton.

INSTITUTIONAL PLANTS.

Natural Soil or Artificial Sand Filters Without Preparatory Treatment.

Alliance, Fairmount Children's Home.
Dayton, Montgomery County Infirmary.
Gallipolis, Gallia County Infirmary.
Gallipolis, State Hospital for Epileptics, Main Buildings' plant.
Gallipolis State Hospital for Epileptics, Cottage I.
Granville, Denison University and Shepardson's College.
Lancaster Boys' Industrial School.
Mansfield State Reformatory.
Massillon State Hospital.
Morgans, Ohio Institution for Feeble Minded Youth.
Toledo State Hospital.
Wooster, Wayne County Children's Home.

ARTIFICIAL SAND FILTERS WITH PREPARATORY TREATMENT IN SETTLING OR SEPTIC TANKS.

Sandusky, Soldiers' and Sailors' Home.
Warren, Trumbull County Infirmary.
Warrensville, Cleveland Tuberculosis Farm Colony.

COARSE GRAIN FILTERS WITH PREPARATORY TREATMENT IN SETTLING OR SEPTIC TANKS.

Collinwood, Lake Shore and Michigan Southern Railroad Shops.
North Amherst, Ohio Quarries Company.

PREPARATORY TREATMENT ALONE OR NO TREATMENT.

Kenton, Hardin County Infirmary.
Marietta, Washington County Infirmary.

MUNICIPAL PLANTS.

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Alliance. — General View of Plant.

Alliance. — General View During Construction of Tanks.

ALLIANCE.

The city of Alliance is in Stark County on the Mahoning River at a point where the stream has a watershed of about 73 square miles. It has a population of 14,000 as estimated from the census reports. The city is a large manufacturing center, the principal industries of which comprise the manufacture of machinery and heavy iron goods. A number of municipal improvements have been carried out dating from 1883, when a public water supply was installed, water for which was taken from the Mahoning River. According to the reports of the water department, the average daily consumption is about 3,700,000 gallons. The city maintains also 12.5 miles of brick pavement with a total length of streets of 37 miles.

SEWERAGE.

The general system of sanitary sewers of the city as now in use (1907) was built in the year 1896. The system comprises vitrified pipe sewers which range in size from 6 to 18 inches. The sanitary sewage of the city is concentrated at a suitable point where since 1896 the crude sewage has been chemically treated before its direct discharge into the Mahoning River. To the end of 1907, there have been constructed about 32.5 miles of sanitary sewers. This includes an extension of the main sewer and a new outlet, built in October, 1907. This extension consists of 2,600 feet of 24-inch vitrified pipe laid on a 0.1 per cent. grade and provided with 5 manholes and 2 concrete culverts. This new outlet is a temporary one, as it is expected that plans will soon be set on foot to provide for a permanent outfall and facilities for a thorough purification of the Alliance sewage in a sewage purification plant of modern design.

In addition to the sanitary sewers, about four miles of strictly storm sewers have been built as a supplement to drainage afforded by natural watercourses. Although the sanitary sewers are intended to receive domestic wastes alone, yet during storms considerable ground water and roof water enters the sewers, so that during wet weather the sewage flow is high and the sewage itself markedly diluted. From records kept by the city, it is estimated that the sanitary sewers at the present time (1907) serve a population of 6,500 persons as there are about 1,460 house connections to the system. A number of industrial plants are connected to the sewers for sanitary purposes, but aside from the discharge of some tarry wastes from a water gas plant, few discharge waste products which would be of material influence upon the ordinarily strictly domestic sewage of the city. The sanitary industrial connections to the Alliance sewers are listed as follows:

	Number.	Persons Served.
Iron Industries	6	3,400
Miscellaneous	6	520
Brewery	1	25
Gas Works	1	25
Railroad Stations	2	variable
Hotels	3	"

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In July, 1894, a number of petitioners urged the State Board of Health to take steps to abate a nuisance alleged to be due to the discharge of sewage into a certain drain near the residential section of the city. After a thorough in-

vestigation, the Board advised the purification of the sewage of the city to abate the existing nuisance and to protect the Mahoning River, the waters of which are used as a source of water supply by several towns and cities in the river valley below. In view of this recommendation and also on account of threatened legal proceedings, the city retained a sanitary engineer to design a complete system of sanitary sewers and to provide for sewage purification.

It was about this date that chemical precipitation plants were much in favor and hence a plant of this type was proposed. The plans for the treatment of the Alliance sewage were finally submitted to the State Board of Health and were approved in August, 1895. As built, in general the plant comprises settling tanks for the sedimentation of the chemically precipitated sewage, means for collecting, pumping and pressing the resulting sludge and a suitable building for preparing the chemicals, sludge pressing and for the development of power for the operation of the required machinery.

EXAMINATIONS AND INSPECTIONS.

This plant was visited in 1906 on April 12 and August 8-10, and in 1907 on January 9, July 18 and October 31. A detailed examination was made on August 8-10, 1906. The remaining visits were for purposes of inspection only.

DESCRIPTION OF PLANT.

The Alliance sewage plant is located on a 1.33-acre strip of land in the southern part of the city adjacent to the built up portion. The nearest house is only 200 feet distant and besides there are a number of houses in a radius of 600 feet.

Power Plant.

To furnish steam for the operation of the stirring devices and for pressing sludge, there is provided one 40 H. P. horizontal tubular boiler. The stirring devices are operated by an 18 H. P. vertical engine connected by belting. The boiler, engine and apparatus for applying chemicals are contained in a two story brick building, approximately 30 x 60 feet in plan. The upper story contains the chemical mixing apparatus, and is so arranged as to be accessible from the street by a driveway, thus avoiding the necessity of elevating the material.

Apparatus for Applying Chemicals.

The original plans called for the use of both sulphate of alumina and lime, and for this purpose there were provided two sets of dissolving tanks and solution tanks. The lime tank which is alone used at the present time (1907) consists of an iron reservoir 6 feet long, 4 feet wide and 2 feet 6 inches deep, and of about 450 gallons capacity. It is constructed of 1/8-inch wrought iron. An opening in the bottom, ordinarily closed with a wooden plug, enables the contents of the tank to be discharged into the solution tank on the floor below. Water for slaking purposes is obtained through a 2-inch line.

The solution tank is of iron 5 feet in diameter and 6 feet deep, and of 880 gallons capacity. To maintain the milk of lime of uniform strength, a stirring apparatus is provided consisting of iron paddles operated by worm gears and belted to the vertical engine, already described. The discharge from the solution tank is controlled by a gate valve.

Screens.

The original plans provided for screening the crude sewage prior to the application of the chemicals. This screening has been abandoned for some years and during this investigation the sewage has received only the rough screening afforded by ½-inch iron rods, 4 feet long and 8 inches high. This screen has an area of 2.67 square feet and is located at the entrance to the first sedimentation basin. The screen has a clear opening of 2 inches and is set vertically.

At the outlet of the third and last settling basin there is provided a second screen of similar dimensions composed also of ½-inch iron rods set, however, ½ inch c. to c., or ½-inch apart in the clear,

Grit Chambers.

No provisions are made for the separate retention of heavier mineral matters of the crude sewage, but the inlet channel provides a considerable reduction in the velocity of flow and hence causes some deposition of suspended matters.

Chemical Precipitation Tanks.

For the sedimentation of the chemically treated sewage, there are three uncovered tanks built of brick with stone copings. Sewage from the main 18-inch sewer discharges at the plant into a 3-foot channel into which the lime solution is discharged. The limed sewage then flows through some 50 feet of open channel into the first precipitation tank. The three tanks are each 40 x 80 feet in plan and from 5 feet 6 inches to 6 feet 6 inches deep with an average depth of 6 feet and a capacity to the flow line of 40,000 gallons each. The walls of the tank are constructed of brick 24 inches thick and the bottom of concrete 6 inches thick.

Inlets and Outlets. The 3-foot channel which extends through the operating building widens just outside to 8 feet, and serves as the inlet channel for any one of the three tanks. Each tank has three openings, two of which lead from this channel and one into the adjacent tank. These openings are 4 feet wide and about 18 inches deep. The flow through them is controlled by stop planks.

Baffles. Practically no special efforts are made to retard by baffles the movement of the sewage in the tanks proper. The stop planks located at the outlets and inlets of the tanks, however, serve practically as scum baffles and arrest considerable floating material and grease.

Sludge Drains. Two lines of sludge drains are provided and they extend from the corners of each tank to a central sludge channel located along the center line of the three tanks. The branch drains are 15 inches wide and 4 to 8 inches deep. The main sludge channel is 24 inches wide and 12 inches deep. Further to facilitate a collection of the sludge, the entire floor of the three tanks slopes towards the sludge well 1 to 40.

By-pass. A few feet above the entrance to the power building there is located a manhole which contains a wooden gate whereby the entire crude sewage flow may be discharged through a "Y" into the river.

It is also possible to discharge the sewage through the main 8-foot channel directly to the river. The channel is usually closed by stop planks.

Aerating Channel. Sewage flow from the third tank takes place on to a series of steps which extend the full width of the channel. This feature provides a fall of about 10 feet, and thus induces considerable aeration.

Measuring Weirs. No permanent facilities are provided for measuring the sewage flow, but since the spring of 1906 a wooden weir has been installed at the outlet of the plant at the head of the aerating channel.

Effluent Discharge. The effluent from the chemical precipitation tanks flows by gravity over the aerating steps already described, through about 100 feet of 18-inch sewer to the Mahoning River. No devices are provided for further purification. Since about December 1, 1907, the effluent has been conducted to the new sewer outlet already described.

Sludge Disposal Area.

The sludge collected in the sludge channels, already described, is led into a brick sludge well 12 feet in diameter and 18 feet deep and of 15,000 gallons capacity. From this well the sludge is pumped by a duplex pump, which has a 4-inch suction and 3-inch discharge, cylinders 8 x 5 x 10 inches and 5-inch hard rubber ball valves. The ultimate disposal of the sludge is provided for by the installation of a 50 compartment sludge press. To remove the pressed sludge, there is provided a small car and a track whereby the pressed cake may be taken to a suitable dumping ground.

SEWAGE FLOW.

Beginning shortly after the preliminary inspection of this plant, the officials in charge have made daily records of features of operation, including measurements of the sewage flow which have been observed daily by means of a weir constructed for that purpose. From these data tabulated in Table No. 1 as monthly averages, it appears that during the special investigation, there has been a gradual increase in the quantity of crude sewage. The data further indicate the general effect of wet weather, ground water leakage and storms upon the quantity of crude sewage to be treated at Alliance. Considering the average sewage flow at the close of the investigation (December, 1907) to be at the rate of 1,600,000 gallons in 24 hours, the flow per person tributary reaches the high figure of 246 gallons. The large per capita flow is probably in large part to be explained by the fact, as stated by the city officials, that in many instances the sewers are laid in districts where the soil is very moist and further by the fact that the flush tanks in use have in considerable part been operated with a flow of water equivalent to the full bore of a ¾-inch iron pipe under city water pressure. Several attempts have been made to reduce the period of discharge of the flush tanks, but it is stated that the character of the public water supply of the city is such that as soon as the faucets controlling the flush tanks are choked down, serious stoppages result and thus render the practice impracticable.

The average water consumption from the records of the water department is about 3,700,000 gallons daily, and it is evident that a considerable quantity of water is used for manufacturing purposes and is discharged directly into the Mahoning River or into storm water drains and natural water-courses. There is also a considerable quantity of water used by railroads.

TABLE NO. 1.

Average Sewage Flow by Months.

Month — 1906–07.	Temp. deg. F.		Rainfall (Inches).	Sewage Flow Gallons in 24 Hours.		
	Air.	Sewage.		Maximum.	Minimum.	Average.
1906.						
May	69	52	0.47	1,570,000	792,000	915,000
June	72	57	3.01	1,440,000	1,080,000	1,310,000
July	74	46	5.15	1,620,000	1,041,000	1,292,000
August	76	45	2.19	1,760,000	1,280,000	1,380,000
September	69	53	2.13	1,370,000	1,290,000	1,330,000
October	55	45	4.50	1,370,000	1,290,000	1,350,000
November	42	37	2.00	1,370,000	1,290,000	1,310,000
December	34	32	2.65	1,410,000	1,220,000	1,360,000
1907.						
January	30	28	3.56	1,542,000	1,370,000	1,480,000
February	21	41	0.95	1,550,000	1,455,000	1,510,000
March	44	43	3.95	1,720,000	1,455,000	1,530,000
April	44	47	2.73	1,414,000	1,248,000	1,294,000
May	.....	.....	.....	.....	.....	.....
June	66	56	4.62	1,710,000	1,484,000	1,627,000
July	73	65	1.64	1,710,000	1,660,000	1,687,000
August	72	68	0.60	1,710,000	1,660,000	1,670,000
September	68	68	1.40	2,170,000	2,080,000	2,110,000
October	49	65	2.93	2,170,000	2,080,000	1,980,000
November	40	59	.....	1,730,000	1,530,000	1,570,000

During the single detailed examination of this plant, weir measurements were made at half hourly intervals to indicate the proportionate quantity of crude sewage for different hours of the day. These data indicated the sewage on August 8-9, 1906, to average about 1,400,000 gallons with a maximum flow of 1,570,000 gallons occurring at 12:00 o'clock noon and 2:30 o'clock P. M. and a minimum flow of 1,200,000 gallons obtaining in the early morning hours. The relation of the sewage flow at different hours of the day to the average is listed as follows:

TABLE NO. 2.

Relation to the Average Flow of the Flow During Different Hours of the Day on August 8-9, 1906.

Hour.	Rate of Flow, Gals. in 24 Hrs.	Percentage of Average.	Hour.	Rate of Flow, Gals. in 24 Hrs.	Percentage of Average.
9 A. M.	1,370,000	98	8 P. M.	1,490,000	106
10 "	1,444,000	103	9 "	1,490,000	106
11 "	1,444,000	103	10 "	1,444,000	103
12 "	1,570,000	112	11 "	1,370,000	98
1 P. M.	1,490,000	106	12 "	1,240,000	88
2 "	1,570,000	107	1 A. M.	1,240,000	88
3 "	1,530,000	109	2 "	1,280,000	91
4 "	1,530,000	109	3 "	1,200,000	85
5 "	1,444,000	103	4 "	1,200,000	85
6 "	1,370,000	98	5 "	1,200,000	85
7 "	1,490,000	106	6 "	1,444,000	103

COMPOSITION OF CRUDE SEWAGE.

As indicated by the high per capita sewage flow just discussed, the crude Alliance sewage is generally very highly diluted. While the sewage ordinarily is of a strictly domestic character, during the detailed examination of the plant it was learned that at rare intervals certain quantities of tarry matters are discharged from a water gas plant operated in the city. As the by-products of the manufacture of water gas are valuable, it is obvious that their discharge is not permitted regularly by the gas works' officials and as a matter of fact on those occasions when tarry wastes have been in evidence in the Alliance sewage, their presence is to be explained by inadvertence on the part of the operators of the water gas plant.

Information as to the general character of the crude sewage obtained upon the single examination of the plant is tabulated at the close of this discussion. The data clearly indicate the general weakness of the sewage. Of special interest is the character of the night sewage to which no lime is applied.

OPERATION.

Until May 1, 1907, a foreman and assistant have been in charge of the operation of the plant. In June an additional assistant was engaged, and in July and continuing until the close of the investigation a day and night force were employed consisting of two men for each shift.

The operation of this plant relates chiefly to the application of milk of lime and to the subsequent disposal of the resulting sludge.

Application of Lime.

The general practice with regard to the application of lime has been substantially the same throughout this investigation, although occasionally the

quantity of lime applied has varied and at times its use has been entirely discontinued. During the summer of 1907, the plant caused such a nuisance in the Mahoning River near the city that the quantity of lime used was greatly increased in the hope of reducing the marked pollution of the river, produced by the discharge of the treated sewage. During 1906, the lime used was what is known as hydrated lime which analyses, made in the laboratory of the Board, showed to contain 42 per cent. available calcium oxide (CaO). Subsequently, in the early part of 1907 a grade of local brown lime was substituted.

While lime is generally applied in three doses of four bushels each, this is not always the case and during this investigation the quantity of lime used daily ranged from 300 to 3,080 pounds. When hydrated lime was used no slaking was, of course, necessary, but at the present time (Dec., 1907) the charge of lime is placed into the slaking tank, is covered with cold water and is allowed to stand until ready for use. The slaked lime flows by gravity to the lime solution tanks, whence it is discharged into the sewage. During the single detailed examination of this plant, the application of lime continued from about 6:00 o'clock A. M. until 4:30 o'clock P. M. On the inspection made on October 31, 1907, however, the application of lime had ceased at 2:00 o'clock P. M., and it was stated that the entire charge of lime for the day had been applied in the space of 2.5 hours. The foul condition of the Mahoning River below the sewer outlet, the by-passing of strong day sewage as observed during one inspection and the frequent stoppage of the lime feed furnish sufficient evidence to indicate strongly that the application of lime is very irregular. No attempt is made to treat the evening and the night flows, respectively, but it is assumed that the large quantity of lime used during the day time will aid in the precipitation of the suspended matter entering the first settling tank during the late afternoon, evening and night, respectively. The wide range in the strength of the milk of lime actually applied to the crude sewage was learned from the analysis of a series of samples of the milk of lime solution collected during the detailed examination. The results were as follows:

TABLE NO. 3.

Strength of Milk of Lime.

Hour.	CaO Grains per Gallon.
7:30 A. M.	2,290
8:30 "	738
1:00 P. M.	1,770
2:00 "	523
3:00 "	572

The daily records kept at this plant list the total quantity of lime used daily throughout the greater part of the period covered by this investigation. Expressed as averages by months and taken in connection with the average sewage flow by months the quantity of crude lime applied ranged from 5.6 to 10.7 grains per gallon and averaged 7.9 grains per gallon. The following table illustrates the range in the quantity of lime applied by months during 1906 and 1907.

TABLE NO. 4.

Quantity of Lime Applied.

Months — 1906–07.	Quantity of Lime Applied.		Grains Per Gallon — Average.
	Pounds Daily.	Tons per Million Gallons.	
1906.			
May	900	.47	7.1
June	1,120	.43	6.0
July	1,080	.42	5.9
August	1,170	.42	5.9
September	1,440	.54	7.6
October	1,890	.70	9.8
November	2,000	.76	10.7
December	1,830	.67	9.4
1907.			
January	1,730	.58	8.1
February	1,760	.58	8.1
March	1,720	.56	7.9
April	1,810	.70	9.8
May	.....	.....	.....
June	1,750	.54	7.6
July	2,180	.65	9.1
August	2,330	.70	9.8
September	2,230	.54	7.6
October	1,590	.40	5.6
November	1,350	.43	6.0

Sedimentation Basins.

The lime treated sewage roughly screened through the coarse screens now in use flows into the first of the three sedimentation basins. The capacity of these basins in terms of the average present (1907) sewage flow is only about 0.6 hour for one tank, or 1.8 hours for the three tanks. Under ordinary conditions the tanks are used in series until it is necessary to remove the sludge from the first tank when the limed sewage is directed into the second tank.

Sludge Disposal.

The disposal of the sludge is of course an important feature of the plant. The Alliance plant is now the only example in the state of a plant where chemically precipitated sludge is pressed. Throughout the greater part of this investigation it was the practice to clean the first of the three settling tanks three times a week, the second tank twice a week, and the third tank once in two weeks.

About two hours before drawing off a tank for cleaning, sewage is diverted to the second tank in order to allow a period of quiescent subsidence prior to the removal of the sludge. At the end of this two-hour period, the supernatant sewage is drawn off directly into the Mahoning River through the hinged outlets practically to the surface of the deposited sludge* The sludge is then forced with "pushers" into the sludge well, whence after the addition of about 200 pounds of lime for each filling of the well it is pumped into the sludge press. Analyses made

during this investigation indicate that the sludge contains on an average about 88 per cent. of water. Until the summer of 1907 about eight presses of 1,500 pounds of sludge cake each were made daily; since that time the quantity of sludge pressed has varied and in the summer of 1907 was greatly increased. (See Table No. 5). The pressed cake resulting from 1,500 pounds of wet sludge weighs about 6 tons or about 30 pounds per cake. Measurements made during the single detailed examination of the plant indicated that the sludge pressed on that day was about 27 cubic yards. When pressed, the resulting sludge cake on analysis was found to contain 47 per cent. water. The pressed sludge is placed into a car operating on a track and leading to a dumping ground near the river. A considerable quantity of pressed sludge has accumulated but does not appear to be troublesome due to odors. It is stated that farmers near Alliance from time to time carry away considerable pressed sludge cake to be used as fertilizer. This demand for sludge cake, because of its fertilizing value, is somewhat unusual and is perhaps explained by the fact that the soil in certain parts of Stark County is somewhat poor in lime and that the sludge cake appears to supply this essential ingredient.

No sludge pressing was carried out in April, 1907, and less than the required amount in May and June, 1907, so that in the summer of 1907 the accumulation of sludge became so great and the imperfectly treated sewage caused such a nuisance in the river that it was necessary to double the operating force in order to operate the sludge press day and night. Evidence is strong that the Alliance sewage at times during the spring and summer of 1907 received no lime treatment and that no sludge pressing was carried out. The necessary increased amount of sludge pressing in the summer and fall of 1907 is illustrated by the following table, in which are listed certain data relative to sludge disposal at this plant.

* In 1908, a 1,000,000-gallon centrifugal pump was installed to pump the supernatant sewage into the inlet channel instead of discharging it directly into the river. This was necessitated because of the decided nuisance caused by the former practice.

TABLE NO. 5.

Sludge Disposal.

Months — 1906–07.	Sludge Cake.	
	Pounds.	Tons per million gallons.
1906.		
May	92,500	1.6
June	106,400	1.3
July	120,000	1.5
August	137,100	1.6
September	159,500	2.0
October	181,400	2.2
November	99,500	1.3
December	145,500	1.7
1907.		
January	102,500	1.1
February	118,000	1.4

TABLE NO. 5 — Concluded.

Months — 1907.	Sludge Cake.	
	Pounds.	Tons per million gallons.
1907.		
March	120,000	1.3
April	120,000	1.5
May*	.....	.....
June†	190,500	2.0
July	383,000	3.7
August	404,510	3.9
September	421,500	3.3
October	339,000	2.8
November	303,000	3.2
December	210,500	2.3

* Sludge press not operated.
† Sludge pressing day and night.

EFFICIENCY.

The efficiency of the plant has been learned from the five visits made during this investigation and of special interest are data collected during the single detailed examination on August 8th, 1906. The preliminary inspection in the spring of 1906, indicated the plant to be in fair condition, and at that time the discharge of the lime treated sewage apparently produced no nuisance in the river below the point at which the effluent discharged. With the advent of warmer weather, however, a decided nuisance developed in view of deposits of sludge along the shores of the Mahoning River. This condition led to the filing with the State Board of Health of a complaint as to a nuisance alleged to be caused by the Alliance sewage plant.

The detailed examination made on August 8-9, 1906, followed shortly after the Board had been advised of the alleged nuisance and furnished ample evidence of its existence.

In general, the results obtained on this detailed examination showed that very poor efficiency was being obtained by the lime treatment. On the day of the detailed examination lime was applied from 6:00 o'clock A .M. to about 4:30 o'clock P. M. to the extent of 1,400 pounds for the day, or roughly 7.0 grains per gallon based upon the average sewage flow for the day. The analyses of the samples of the crude sewage and the effluent collected on this examination indicated a suspended matter removal of only 50 per cent. Moreover, the dissolved organic matter as indicated by the dissolved oxygen consumed and the dissolved organic nitrogen were considerably higher than were these data for the crude sewage, illustrating the well known solvent action of lime on suspended organic material; as a result of which the lime treatment of sewage produces an effluent which at times may be more strongly organic and hence more offensive than the crude sewage itself. The treated effluent on this examination and in general is distinctly putrescible and contains unstable organic matter, both in suspension and in solution, a feature which may be taken in explanation of the

large masses of putrefying sludge which are noted along the shore of the river below the discharge of the effluent from the plant. The general conclusions drawn from the detailed examination of the plant were that the lime treatment at Alliance does not measurably reduce the organic and polluting character of the crude sewage, but that the effluent tends to be somewhat more offensive than the crude sewage would be were it discharged after receiving plain sedimentation only. This feature appears to be in part caused by the irregular application of lime and in a large part by the solvent action of lime on organic matters, as already mentioned. It is further to be mentioned that the short period of flow in the settling tanks (1.8 hours at the present time (1907) average rate of sewage flow), does not afford sufficient opportunity for sedimentation following chemical treatment and suggests that the capacity of the plant has long since been exceeded.

In the following table certain of the analytical data obtained during the single examination of this plant are presented with a view to showing the percentage removal of the several constituents of the crude sewage by the rough lime treatment as carried out on August 8-9, 1906.

TABLE NO. 6.

Removal of Organic and Suspended Matter.

Date	Parts per Million.								Percentage Removal.			
	Oxygen Consumed		Organic Nitrogen		Suspended Matter							
					Total		Volatile				Suspended Matter.	
	Eff.	Sew.	Sew.	Eff.	Sew.	Eff.	Sew.	Eff.	Oxygen Consumed.	Nitrogen.	Total.	Volatile.
August 8, 1906.....	21	26	8.4	10.0	45	20	39	21	—19	—16	56	46

Note negative removal of organic matter.

About six months later the Alliance plant was visited again and in general conditions were found to be practically the same in regard to the pollution of the river, but on account of winter weather nuisance from odors from exposed sludge banks in the river were greatly reduced as would naturally be expected. It was found that at 3:00 o'clock P. M. the application of lime had ceased for the day and further that a large part of the crude sewage was being by-passed directly to the river. Evidence obtained during this inspection seemed strong that the sewage had for some time past been discharged in part without lime treatment.

The effluent from the plant possessed considerable odor. Odors were marked in the sludge pressing room but no special nuisance could be said to be attributable to the heap of pressed sludge cake adjacent to the river.

In the summer of 1907, a third visit was paid the plant and there was discussed the desirability of a changed outlet and a new sewage plant to provide for the actual purification of the sewage of the city. The operation of the Alliance plant was found to be practically the same as during the winter months with some strong evidence that considerable sewage had been by-passed to the river. It was found that there had been very little sludge pressing during the spring and late summer and that on this account it had been necessary to double

the operating force, that the accumulation of sludge might not become too excessive. Complaints from nuisance in the river continued to be made to the state officials and the poor results obtained from lime treatment at Alliance undoubtedly explain the nuisance which exists in the river during the low flows of the summer months.

The final inspection in October, 1907, indicated similar conditions with respect to the inefficiency of the present plant. It was found that the city authorities had already proceeded with the construction of a new sewer outlet with a view to discharging the putrescible effluent from the plant some distance below the homes of those persons who had remonstrated on account of the odors arising from the river.

SUMMARY.

Evidence collected during these inspections strongly indicates that the chemical precipitation plant at Alliance is inadequate to solve the sewage problem of the city in view of the largely increased flow of sewage. The plant at best affords a removal of the coarser particles of suspended matter, but offsetting this improvement, the lime applied exerts its well-known solvent action on dissolved organic matter and causes the treated effluent to be more putrescible than the crude sewage would be were it subjected to plain sedimentation only. Furthermore, the small capacity of the settling tanks affords a percentage removal of only 50 per cent. of the total suspended matters, a small reduction for chemical precipitation, perhaps explained in part as well by the very irregular application of lime.

The need for a plant along modern lines to provide for the purification of the sewage of the city of Alliance has certainly been brought out by this investigation. Plans for a modern sewage purification plant should be prepared without further delay for it is evident that the new outlet has merely transferred the point of local nuisance farther down the river. It should also be borne in mind that this chemical precipitation plant effects merely a partial clarification of the Alliance sewage and that the effluent as discharged into the Mahoning River contains a large part of the impurities in the crude sewage and causes unsightly and obnoxious deposits of sludge on the bed of the stream. There is further to be considered the possibility that in times of high water these deposits are washed down the stream to the possible detriment of water supplies drawn from the Mahoning River below the city of Alliance. Another fact to be considered is a reduction in the high present operating expenses. A comparison of operating expenses of modern plants to that at Alliance shows that the balance is very largely in favor of the former or in other words, the present operating costs at Alliance would go far toward paying interests charges upon a modern plant.

COSTS.

Up to the year 1897, the constructional costs of this plant were about $22,000. Including the new sewer outlet built in 1907 at a cost of $4,712.50, the total cost of construction to date is $26,712.50.

Records kept by the city officials afford interesting information regarding costs. The total cost of operation for 1906 was $2,942.29 and for 1907 it is estimated at $3,600, which is 45 cents per person tributary for the year 1906 and 55 cents per person tributary for 1907. In the year 1907, the average cost per million gallons of sewage treated ranged from about $5.00 to $8.35. It is interesting to compare the present costs with those of past years. In the report of the State Board of Health for 1903 the cost per person tributary to the sewers

for the years 1898 to 1900 inclusive and for the year 1903, are given as 20, 21, 21 and 19 cents, respectively.* The total operating costs for 1903 were $2,093.80. The higher operating costs for the year 1907 as against those for 1906 are explained by the extra labor employed since July, 1907, together with the use of a larger quantity of lime and the necessity for pressing a constantly increasing quantity of sludge, all of which has been done with a view to abating the decided nuisance caused by the imperfectly treated sewage of the city.

The following itemized cost of operation by months is of special interest as illustrating the somewhat high operating costs of this chemical precipitation plant.

* Pop. tributary: 1898, 1,300; 1899, 1,500; 1900, 1,700; 1903, 4,000.

TABLE NO. 7.

Costs of Operation by Months for the Year 1907.

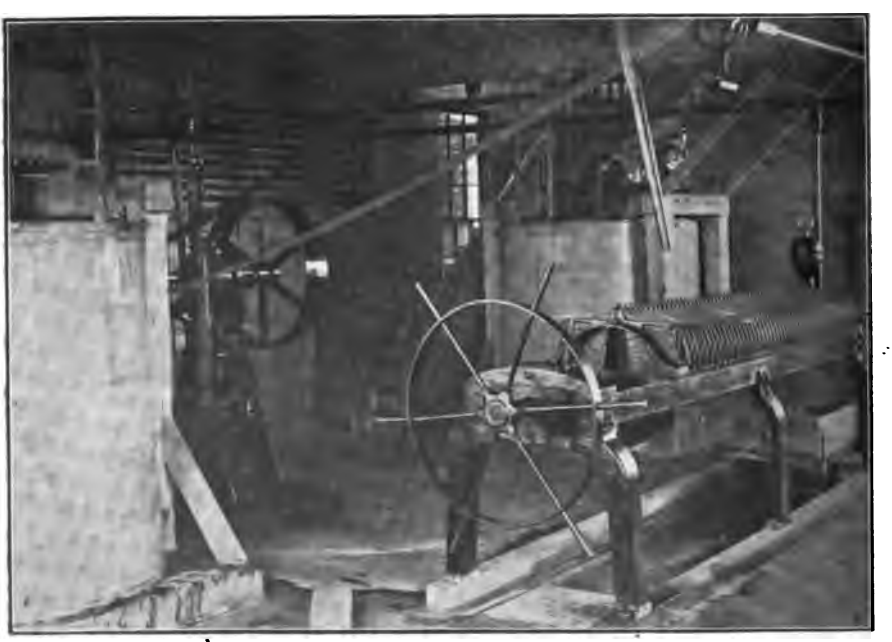
1907 Month	Labor.		Coal.		Lime.	Oil and Waste.	Total for Month.	Per Million Gallons.
	Supt.	Assts.	Tons.	Cost.				
February	$40	$48 00	9.65	$19 29	$104 51	$1 78	$213 58	$5 05
March	40	52 00	9.06	18 11	124 08	2 03	236 22	5 00
April	40	52 00	9.93	19 86	122 31	2 03	236 20	6 10
May	40	54 00	10.95	21 90	138 60	2 03	256 53	.....
June	40	100 00	10.46	20 91	129 36	2 03	292 30	6 00
July	40	138 00	16.11	32 21	165 78	3 04	379 03	7 25
August	40	162 00	18.52	37 04	187 38	3 70	430 14	8 35
September	40	150 00	16.85	33 70	171 49	3 59	398 78	6 30
October	40	173 00	12.45	24 90	118 08	3 72	359 70	5 85
November	40	169 00	11.04	22 07	108 54	3 72	343 33	7 30
December	40	116 50	9.05	19 06	108 00	3 72	287 28	6 15

TABLE NO. 8.

Results of Chemical Analyses.

Date 1906.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.													
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.
					Organic.		Free Ammonia.	Nitrites.	Nitrates.							
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.				
Crude Sewage.																
Aug. 8, 1906.....	6:30 A.- 5:30 P.	72	28	23	11.5	7.8	6.0	0.00	.....	22	67	58	28	.....	.....	32
Aug. 8-9, 1906....	6:00 P.- 6:00 A.	71	13	11	5.2	2.8	1.8	.04	.....	8	22	20	10	.....	.....	12
Weighted Av'ge.....		72	21	17	8.4	5.3	3.9	.02	.....	15	45	39	19	.....	.....	22
Effluent Settling Basins.																
Aug. 8, 1906.....	6:00 A.- 5:30 P.	72	29	21	12.7	8.9	7.2	.01	.....	20	33	27	neutral.	.....	+	.....
Aug. 8-9 1906....	6:00 P.- 6:00 A.	71	23	19	7.3	4.7	3.6	.01	0.0	18	20	21	.....	.....	+	.....

Canton. — General View of Plant.



Canton. — Solution Tanks and Sludge Press.

CANTON.

The city of Canton is in the east-central portion of Stark County and lies between the east and west branches of Nimishillen Creek, just north of their confluence. The stream is a tributary of the Muskingum River and at Canton has a watershed of about 100 square miles. The dry weather flow of the creek is from 3 to 4 cubic feet per second.

The population of Canton by exterpolation from the census reports of 1890 and 1900 is 34,000. Local estimates, however, place the population between 40,000 and 50,000. Canton is a prosperous manufacturing city and embraces a great variety of industries. Its development in recent years has been very rapid and with the rapidly increasing population many public improvements have been carried out. In 1907, according to the city reports there were 21.44 miles of paved streets, 68.5 miles of sanitary sewers and 15.6 miles of storm sewers. A public water supply installed in the year 1869 and derived from deep wells supplies daily a consumption of about 4,273,000 gallons as recorded in the report of the department of waterworks for the year 1906.

SEWERAGE.

The first sewers were constructed in the early seventies and were primarily for the removal of storm water. Since that date the storm water sewerage has been largely developed and the storm sewers alone are now about 15.6 miles in length. The sanitary sewers are constructed of vitrified sewer pipe which ranges in size from 6 to 20 inches. The main trunk sewer which leads to the purification plant is a brick egg-shaped sewer with a cross section about 30x36 inches.

Of the 50,000 population about 23,500, or 47 per cent. are connected to the sewers, on the basis of five persons per connection, of which there are about 4,700. While practically no industrial wastes enter the sewers, yet for sanitary purposes there are a number of manufacturing concerns connected with the sewers as well as a number of public buildings. The principal sanitary connections other than those which are purely residential are listed as follows:

Breweries	3	School houses	15
Business blocks	61	Iron industries	32
Agricultural implements	7	Hotels	8
Foundries	6	Soap works	1

CONDITIONS LEADING TO SEWAGE PURIFICATION.

As early as the year 1878, conditions at Canton were such that some system of sewerage was necessary to safeguard the health and welfare of the citizens. As a preliminary step, a consulting engineer was retained who presented a report recommending a separate system of sewers. Four years later, in 1882, there was appointed a board of sewer commissioners, which in 1883 retained an engineer to prepare plans for a sanitary sewerage system. The project was submitted to popular vote but was defeated by a majority of about 600.

The growth of the city was so rapid, however, and the need of sewerage so pressing, that the project was revived in 1887, and still another engineer was retained. A report presented by him in 1888 discussed fully the problem of sewering the city of Canton and stated that there was practically no possibility of disposing of the sewage of the city by dilution owing to the limited flow of

Nimishillen Creek, and that furthermore, riparian owners located on the shore of the creek had intimated that they would at once enter suit unless steps were taken to provide for the treatment of the Canton sewage. The system of sewage treatment advised was chemical precipitation, which was considered to be the most satsifactory type of treatment to adopt as the other two systems then in use in the United States, namely, broad irrigation and intermittent filtration did not appear feasible on account of the absence of suitable sites of sufficient area and further in view of the probability that these two systems would not be well adapted to meet the future needs of the rapidly growing city of Canton.

The plant built in 1893 comprises facilities for treating the crude sewage with lime followed by sedimentation in brick tanks. Machinery for applying the chemicals are housed in a brick building which contains a power plant for operating a sludge press and for pumping sludge.

EXAMINATIONS AND INSPECTIONS.

During this investigation, the Canton sewage plant was visited on seven occasions as follows: In 1906 on April 12 and Aug. 9–10; in 1907, on Jan. 9, Jan. 16, Feb. 26, July 17–18 and Nov. 1. Detailed examinations were made on Ang. 9-10, 1906; Jan. 16, Feb. 26 and July 17-18, 1907. The remaining visits were for inspection only.

DESCRIPTION OF PLANT.

The plant as it exists at the present time differs little from the original and is located on a 28-acre tract of land about two miles south of the center of the city bordering on Nimishillen Creek; to this plant the crude sewage is conducted by gravity.

Power Plant.

For the operation of the stirring devices and for pressing sludge, there is provided an 80 H. P. horizontal tubular boiler 54 inches in diameter and 12 feet long with a brick setting with full arched front and a wrought iron stack 43 feet high. The stirring devices are operated by an 18 H. P. vertical engine to which they are connected by belting. The boiler and power plant are contained in a frame building 60x68 feet in plan. The lower floor contains the boiler, pump room and sludge pressing room, and the second story contains the chemical store room, lime storage bins and slaking tank.

Apparatus for Applying Chemicals.

To treat the crude sewage with lime, a dissolving or slaking tank is provided. This is of $\frac{1}{8}$-inch iron and is 4x6 feet in plan, 2 feet 6 inches deep and of about 450 gallons capacity. The slaked lime is discharged through an opening in the bottom, flanged, and raised $\frac{3}{4}$ inch above the bottom of the tank and protected by a screen containing $\frac{1}{4}$-inch holes.

The solution tank is of iron 4 feet 3 inches x 8 feet 6 inches in plan and 6 feet deep and of 303 gallons capacity per vertical foot. Two sets of rotating arms operated by worm gears driven by belting connected to the 18 H. P. vertical engine provide for the continuous agitation of the milk of lime.

From the solution tank the lime solution flows through a 3-inch iron pipe provided at its outlet end with an ingenious tripping device which automatically opens and closes a valve which allows the discharge of the full bore of the pipe at all times. The operation of this device is very satisfactory and no clogging results.

Screens.

The crude sewage from the main sewer is first screened through 3/16x1¼-inch iron bars with a clear opening of ⅝ inch. The screen is 2 feet 6 inches x 4 feet 2 inches in plan, about 10 square feet in area and is inclined 20 degrees to the vertical. It is contained in an inlet channel 4 feet 2 inches wide which virtually serves as a screen chamber. A horizontal wooden platform 12 inches wide extends the full length of the screen and forms a shelf upon which the screenings may be drawn prior to their disposal under the boiler.

Chemical Precipitation Tanks.

As the sewers are on the separate system, grit chambers were not considered essential and whatever heavy material is carried by the crude sewage is intercepted in the inlet channel to the chemical precipitation tanks. These are uncovered tanks, four in number and constructed of brick capped with stone. The walls are 2 feet thick and are plastered with 1-inch Portland cement mortar. The bottom of the tank is 13.5 inches thick. Each tank is 50x96 feet in plan with an average depth of 4 feet 11 inches. The depth to the flow line ranges from 4 to 6 feet and the average capacity of each tank is 175,000 gallons.

Inlets and Outlets. Sewage directly from the screen chamber flows through a 10-foot inlet channel controlled by wooden stop planks. Each tank has three openings, each 4 feet wide, two of which open into the inlet channel and one into the adjacent tank. The outlets from the tank are similar to the inlets and at the channel end there are two outlets for each tank. The flow through the tanks is controlled by stop planks set in stop plank grooves.

Baffles. There are no baffles to control the flow in the tanks themselves, but the stop planks at the inlets and outlets serve practically as scum baffles and also provide a means to vary the depth of sewage held in a tank.

Sludge Drains. In each tank there is a sludge channel 2 feet wide and 6 inches deep, which leads to a main sludge channel underneath the main sewage channel in the central dividing wall. To facilitate the discharge of sludge, the floor of the tanks are sloped about 1 in 50 from the central dividing wall to the sludge channel. The tanks are also sloped from sides to center line.

By-pass. On the trunk sewer adjacent to the plant there is a manhole whereby it is possible to divert the entire sewage flow directly to Nimishillen Creek through a 20-inch pipe about 750 feet long. In this manhole are stop plank grooves which allow the insertion of a gate to cut off the flow to the plant.

Aerating Channel. After passing through the four settling tanks in series, the sewage flows over a series of steps 4 feet 6 inches wide which affords a drop of 10 feet 6 inches. This fall tends to introduce considerable oxygen into the clarified effluent.

Measuring Weirs. To measure the crude sewage a rough wooden weir was provided at the outlet. During the last detailed examination, a weir was placed in the inlet channel.

Method of Discharge. The treated sewage after sedimentation in the four settling tanks flows to the creek by gravity through about 600 feet of 24-inch vitrified sewer pipe. The house nearest to the aerating chamber is that of the operator of the plant and is about 100 feet distant. The plant is so situated that there is no danger from high water. The outlet at the creek is generally submerged except during dry weather.

Sludge Disposal Area.

Sludge accumulating in the tanks is discharged at intervals through the central sludge channel and main sludge drain into a sludge well 9 feet 10 inches in diameter and 18 feet deep with a depth to the flow line of 11 feet 8 inches and a capacity of 6630 gallons. Original provisions were to press the sludge, for which purpose there was provided a 50 compartment sludge press to which the sludge was pumped by a centrifugal duplex Voisard sludge force pump with a steam cylinder 7½ inches in diameter and a water cylinder 5 inches in diameter, both with a 10-inch stroke. This pump also was to be used for supplying spring water for the chemical solutions. Sludge pressing has been abandoned for some time past, and sludge has been pumped from the sludge well through about 600 feet of 2.5-inch wrought iron pipe on to a sludge area of about 2.5 acres. This area has been partially underdrained with tile. Along the line of 2.5-inch wrought iron force main a number of tees have been placed and at two points, lines of the 2.5-inch pipe extended laterally, one 300 feet long and the other 200 feet long, so that by means of some 400 feet of rubber hose it is possible to distribute sludge over the sludge area in a fairly uniform manner.

SEWAGE FLOW.

During this investigation certain daily records have been kept by those in charge of the operation of the Canton plant, of the quantity of sewage flow as indicated by weir measurements. These data are accurate only to within about 10 per cent., but they roughly indicate the quantity of crude sewage which during this investigation has averaged about 2,500,000 gallons in 24 hours. The average quantity of sewage during the first detailed examination of the plant was at the rate of 2,720,000 gallons in 24 hours. During the last detailed examination on July 17-18, 1907, a new weir was constructed from which more accurate measurements could be obtained. There was indicated an average flow of 2,120,000 gallons, a maximum rate of 3,100,000 gallons and a minimum rate of 1,450,000 gallons. The maximum rate of flow occurred at 8:00 o'clock a. m. and the minimum at 4:00 o'clock a. m. The average sewage flow in July, 1907, corresponds to a flow per person tributary of 90 gallons. Both detailed examinations for 24 hours were carried out during dry weather.

During wet weather the sewage flow is largely increased on account of the ground water collected by the main trunk sewer, which is in part laid in swampy land. The above average sewage flow, moreover, is no doubt somewhat low in view of the fact that there is considerable leakage at a point where the main trunk sewer is carried across the river in an open pipe of semi-circular cross section. On March 8, 1908, high water in Nimishillen Creek washed away the wooden cradle which comprised the river crossing and since that time the entire sewage flow has passed into the creek at this point. It is probable that the new river crossing will be built in the near future.*

From the records of the water department the total daily average water consumption in 1906 was 4,273,000 gallons. While a part of the public water supply is used for manufacturing purposes and does not reach the sanitary sewers, yet the great difference between the average dry weather sewage flow and the water consumption is doubtless to be explained by the fact that only 47 per cent. of the population have access to the sewers, although a greater part of the inhabitants are supplied with water.

The proportionate quantities of sewage for different hours of the day as found on July 17-18, 1907, are shown in Table No. 9:

TABLE NO. 9.

Relation to the Average Flow of the Flow During Different Hours of the Day on July 17-18, 1907.

Hour.	Rate of Flow — Gals. in 24 Hrs.	Percentage of Average.	Hour.	Rate of Flow — Gals. in 24 Hrs.	Percentage of Average.
3–4 P. M.....	2,490,000	118	3–4 A. M.....	1,560,000	74
4–5 "	2,360,000	111	4–5 "	1,450,000	68
5–6 "	2,100,000	99	5–6 "	1,560,000	74
6–7 "	2,140,000	101	6–7 "	1,600,000	75
7–8 "	2,600,000	123	7–8 "	2,030,000	96
8–9 "	2,320,000	110	8–9 "	2,860,000	135
9–10 "	1,950,000	92	9–10 "	2,610,000	123
10–11 "	1,910,000	90	10–11 "	2,490,000	117
11–12 "	1,830,000	86	11–12 "	2,610,000	123
12 P–1 A.....	1,760,000	83	12 A–1 P.....	2,610,000	123
1–2 A. M.....	1,640,000	77	1–2 P. M.....	2,550,000	120
2–3 "	1,600,000	75	2–3 "	2,320,000	110

* Construction of new cast iron siphon for river crossing completed Aug. 22, '08, at a cost of $1,098.24.

COMPOSITION OF CRUDE SEWAGE.

Analyses of the crude Canton sewage are listed at the close of this section of the report. In each instance, the samples were separated into day and night portions, respectively, and covered the respective periods from 6:00 o'clock a. m. to 10:30 o'clock p. m., and from 11:00 o'clock p. m. to 5:30 o'clock a. m.

The most striking feature of the Canton sewage is the high dilution by ground water as indicated by the unusually low organic and suspended matters, as compared with domestic sewages of cities where ground water leakage is less pronounced. At times, moreover, during this investigation small quantities of dissolved oxygen have been found in the crude sewage. From the analyses as listed beyond, it is clear that during the night the crude sewage is more highly diluted with respect to organic matter than the effluent from the plant which results from the present lime treatment of the crude day sewage. Inspection and analyses indicate that no manufacturing wastes materially affect the strictly domestic character of the Canton sewage.

OPERATION.

The Canton sewage plant is under the general supervision of the board of public service and under the direct supervision of the city engineer. It is operated by a superintendent and assistant during the day and by one attendant at night each of whom is a licensed stationary engineer.

SCREENING.

The crude sewage is first screened. A large indeterminate quantity of material is intercepted and at frequent intervals during the day, the screenings are

raked to a wooden platform above the screen and from time to time are removed and burned under the boilers.

Application of Lime.

For the purposes of this investigation, careful detail records have been kept at the plant as to features of operation and from these records, together with information obtained during the several visits made to the plant, data have been obtained as to the method of applying lime and as to the quantity of lime used.

Slaking. When lime is applied, there are usually four doses daily which are slaked in the slaking tank. The process of slaking consists in adding a measured quantity of crude lime to the slaking tank which contains a considerable quantity of cold water. Steam is then admitted and the mixture is brought practically to the boiling point. In a short time the lime slakes and crumbles to a powder and on its subsequent discharge into the solution tank on the floor below is readily made into a milk of proper strength by the addition of sufficient water. On the day run lime is usually slaked at 10:00 o'clock a. m., 1:00 o'clock p. m. and 5:00 o'clock p. m. and on the night run about 1:00 o'clock a. m.

Character of Milk of Lime. During the detailed examinations of July, 1906, and Aug. 1907, hourly samples have been collected of the milk of lime as applied to the sewage. The lime used at Canton during 1906 was a very low grade product locally obtainable, which analyses made in the laboratory of the State Board of Health have shown to contain about 12 per cent. calcium oxide (CaO). That used in 1907 was of somewhat better quality and analyses showed 35 per cent. available calcium oxide (CaO).

Representative data as to the actual strength of lime applied as obtained on August 9th, 1906, are listed in Table No. 10. These data show a range from 1900 to 3750 grains per gallon calcium oxide (CaO) and an average strength of 2706 grains per gallon.

TABLE NO. 10.

Strength of Milk of Lime.

Hour.	Grains CaO Per Gallon.
7:00 A. M.	2,730
8:00 "	2,290
9:00 "	3,125
10:00 "	2,520
11:00 "	2,100
12:00 "	2,840
1:00 P. M.	1,900
2:00 "	2,780
3:00 "	2,160
4:00 "	2,410
5:00 "	2,580
6:00 "	3,740
7:00 "	2,900
8:00 "	2,750
9:00 "	2,720
10:00 "	3,750
Average	2,706

Quantity Applied. During week days, the total daily consumption of lime is 42 bushels or 3,360 pounds. Of this quantity, the night man slakes 14 bushels and the day man 28 bushels. On Sundays, the quantity of lime is reduced to 1120 pounds and is applied in 12 hours. During this investigation, these quantities of lime were used except from November 27, 1906, to April 24, 1907, when no lime was applied to the Canton sewage. The lime is used on week days for a period of 16 hours, and none at night since between the hours of 1:00 o'clock and 5:00 o'clock a. m. the sewage is especially dilute and is of a character such that very little improvement could probably be effected by lime treatment.

Based upon the average sewage flow on week days, as indicated from the daily hourly measurements of the rate of sewage flow, the average quantity of lime applied is about 13.6 grains per gallon, or roughly 1 ton per million gallons. These data are based upon a two-thirds flow of sewage during the average period lime is used. On Sundays, the quantity of lime corresponds roughly to 6.8 grains per gallon. The average quantity of lime applied by months is recorded in the following table:

TABLE NO. 11.

*Average Quantity of Lime Applied by Months, Exclusive of Sundays.**

Months — 1906–07.	Average Week Day Sewage Flow — Gals. in 24 Hrs.	Lime Applied.	
		Grains per Gallon.	Tons per million gallons.
June 1906	2,200,000	16.7	1.19
July	2,400,000	15.3	1.09
August	2,600,000	14.2	1.01
September	2,700,000	13.6	0.98
October	2,700,000	13.6	0.98
November	2,800,000	13.2	0.95
December	2,800,000	0	0
January 1907	2,600,000	0	0
February	2,700,000	0	0
March	2,500,000	0	0
April	2,700,000	12.6	0.91
May	2,700,000	12.6	0.91
June	2,700,000	13.6	0.98
July	2,700,000	13.6	0.98
August	2,700,000	13.6	0.98
September	2,800,000	13.2	0.95

*Lime applied 16 hours daily. In 1907, treatment began April 25.

Settling Tanks.

In terms of the average sewage flow, the four tanks operated in series have a capacity of about 6.7 hours. Sewage is usually conducted into the tank adjacent to the main inlet channel except when this tank is out of service for cleaning. During this investigation, interesting studies were made relative to the course of the sewage through the basins and as to the approximate surface velocity. On the visit of July 17, 1907, float measurements indicated the average surface velocity in the first basin to be 205 m. m. per second (2,460 feet per hour);

in the second, third and fourth basins 139 m. m. per second (1,670 feet per hour). These velocities, of course, vary with the sewage flow, but they indicate a comparatively high rate of flow. Notwithstanding the high rate of flow through the tanks, the greater part of the sludge is deposited in the first basin and, moreover, the position of the sludge on the bottom of the basin indicates that the greater part of it is deposited in the first 50 feet and that the sewage actually takes a bow shaped course through the tank. This feature is of special interest since the sewage enters and leaves the tank at the same end with respect to the inlet channel, and will again be referred to in discussing results obtained on the detailed examination made in July, 1907.

Sludge Disposal.

The first tank, of course, intercepts the greatest quantity of suspended matter. It is cleaned on Sunday, Wednesday and Friday nights. Tank No. 2 is cleaned on Monday and Thursday nights and Tank No. 4 on Tuesday and Friday mornings. It is the general practice for the night man to draw off the supernatant sewage and to fill the sludge well. In recent years, the capacity of the well is too small to retain all of the sludge from the first tank so that a second filling of the well is always necessary and at times a third. No sludge is pumped during the night.

In cleaning the tanks, after the supernatant water has been drawn off, one man with a wooden pusher forces the sludge into the central sludge channel and finally supplements this device with water from a 4-inch fire hose with a 1½-inch nozzle. This indeterminate quantity of water which is used in connection with the cleaning of the tanks renders it impossible to obtain from the quantity of sludge, as reported on the monthly blanks, the actual quantity of suspended matter as sludge deposited. The figures, however, represent approximately the total quantity of sludge which has been pumped to the disposal area. The larger area available for sludge disposal made possible by changes in the piping connections and the use of rubber hose, as already described, greatly improved the distribution of sludge over the sludge area. It is the practice to change the position of the discharge of the liquid sludge at frequent intervals with a view to causing the sludge deposits to dry more rapidly.

The daily records kept at the plant have included measurements of the quantity of diluted sludge pumped to the disposal field. These data have been averaged by months and are recorded in Table No. 12. During the period covered by this investigation, when lime has been applied to the sewage the daily quantity of dilute sludge pumped has averaged 14.3 cubic yards per million gallons and for the winter months when no lime has been applied, the quantity of sludge pumped has been only slightly lower, or 13.7 cubic yards per million gallons.

TABLE NO. 12.

Sludge Disposal by Months During 1906-1907.

Months — 1906–1907.	Wet Sludge.	
	Cubic Yards.	Cubic Yards per Million Gallons.
1906.		
June	1,110	17.0
July	1,070	14.8
August	1,450	18.1
September	1,000	12.3
October	1,100	13.3
November	1,250	15.2
December	1,150	13.7
1907.		
January	1,140	13.8
February	990	13.4
March	1,090	14.0
April	1,080	13.3
May	1,190	14.3
June	1,100	13.6
July	1,020	12.2
August	1,180	14.0
September	1,090	13.0

EFFICIENCY.

The inspections and the detailed examinations of this plant have furnished considerable information as to its efficiency. A special study was made of the efficiency of the plant during the winter months when no lime is used as compared with the results obtained during the warmer months of the year, when lime is regularly applied for sixteen hours a day.

The preliminary inspection of this plant indicated a fairly well clarified effluent, but one which was distinctly putrescent. Considerable iron pickling liquors were noted in Nimishillen creek and these wastes no doubt would tend to remove evidences of pollution caused by the discharge of the effluent. It was stated that offensive odors arose from the drying sludge and created a decided nuisance in the immediate neighborhood.

The first detailed examination showed that the plant as operated removes simply the coarser suspended matters and clarifies the sewage to a certain extent, but that the effluent is highly putrescent. The removal of suspended matter was only 2 per cent., presumably to be explained by the fact that the crude sewage contained only 43 parts per million of suspended matter.

Investigation of sludge disposal indicated that the extension of the piping and the improved method of disposing of the sludge, as already described, had tended materially to alleviate the nuisance from odors caused by the exposure of such large quantities of sewage sludge from lime treatment.

An inspection in the winter of 1907 disclosed the fact that no lime was

being used. Complaints from odors due to sludge disposal were stated to be less frequent, but the appearance of this sludge disposal field indicated that the point of application of fresh sludge had not been changed with sufficient frequency.

On the visit of Jan. 16, 1907, samples of the crude sewage and of the effluent from the four basins when the plant was operated without lime were collected at half-hourly intervals from 6:00 o'clock A. M. to 10:00 o'clock P. M. Average samples weighted in proportion to the sewage flow were examined for organic and suspended matters. Very interesting results were obtained and they showed an average removal of suspended matter of about 50 per cent., the greater part of which was effected in the first basin. These results as to the efficiency of the Canton plant when operated on the plain subsidence plan are shown in the following table.

TABLE NO. 13.

Analyses of Crude and Settled Sewages and Efficiency of Plain Subsidence Under Winter Operation.

Source.	Parts Per Million.					Percentage Removal.			
	Oxygen Consumed.	Nitrogen as		Suspended Matter.		Oxygen Consumed.	Organic Nitrogen.	Suspended Matter.	
		Organic.	Free Ammonia.	Volatile.	Total.			Total.	Volatile.
Crude Sewage	40	16.9	11.0	83	42	.....	.....	.....	.....
1st Basin	37	17.3	8.2	46	33	7	—2	45	22
2nd Basin	36	12.7	8.0	41	30	10	25	51	29
3rd Basin	33	12.9	7.0	42	28	17	24	49	33
4th Basin	32	10.1	6.6	41	29	20	40	51	31

The results obtained from this examination were considered somewhat unusual, especially as they compared favorably with those obtained when lime was being applied to the sewage. Furthermore, they suggested a somewhat low percentage removal, a feature presumably to be attributed to the high velocities of flow in the tanks and the somewhat short period of flow. It was, therefore, deemed advisable to duplicate the work of Jan. 16th. Accordingly, a second test was made on Feb. 26th. Similar data were obtained and they illustrate the progressive removal of suspended and organic matters. The removal of these constituents was again about 51 per cent., 52 per cent. and 57 per cent., as indicated by the suspended matter, the oxygen consumed and the organic nitrogen, respectively.

Additional information regarding the efficiency of the plant when lime is applied was obtained on the last detailed examination carried out on July 17-18, '07. For the sake of comparison with the results obtained on the examination of Jan. 16th, the progressive improvement in the character of the crude sewage is shown in the following table.

TABLE NO. 14.

Removal of Suspended and Organic Matters, on July 17, 1907.

Source.	Parts Per Million.			Percentage Removal.		
	Oxygen Consumed.	Organic Nitrogen.	Suspended Matter.	Oxygen Consumed.	Organic Nitrogen.	Suspended Matter.
Crude Sewage	34	13.6	89	.....	.....	.....
1st Basin	30	11.6	85	12	15	45
2nd Basin	26	8.4	50	24	38	44
3rd Basin	24	6.4	47	29	53	47
4th Basin	23	6.8	49	33	50	45

As already stated, the lime treated sewage leaves each settling tank through the outlet which leads to the central channel adjacent to the inlet and as these studies have shown, the path of travel is bow-shaped as the form in which the sludge is deposited, clearly indicates. During the visit of July 17, 1907, it was decided to duplicate the test on the next day, so operating the plant that the path of sewage would be diagonally across the tanks with the thought that possibly there could be obtained a greater percentage removal of suspended matter. The summarized results tabulated beyond in Table No. 15 show a somewhat greater removal of suspended matter and of organic matter than on the previous day, but as the results did not indicate a material improvement it was not thought necessary to suggest that the operation of the plant be changed. The average sewage flow on this examination was at the rate of 2,160,000 gallons in 24 hours and the average period of flow of the tanks was 8.0 hours. The day rate is, of course, somewhat greater.

Lime Treatment and Plain Sedimentation Compared. On the four detailed examinations of this plant, the last of two days' duration, data have been obtained which allow a comparison between the efficiencies obtained with and without the use of lime to assist sedimentation. While unfortunately the actual strength of the crude sewage in suspended and organic matters was not the same during the several tests, yet the summarized results of the analyses indicate resulting efficiencies under conditions existing when the tests were carried out. These data cover all examinations made during this investigation and are summarized in Table No. 15. It will be noted that lime treatment removes about 50 per cent. of the suspended matter and in the main about 50 per cent. of the organic matter based on the crude screened sewage. Comparing results obtained during the examinations of Jan. 16 and Feb. 26, 1907, to the results obtained during the detailed tests on Aug. 9–10, 1906, and July 17-18, 1907, it is evident that substantially as satisfactory removals are obtained in the former cases. These data are instructive as indicating that the addition of lime to the Canton sewage in quantities as previously stated does not materially improve the character of the resulting effluent over and above that which could be produced by plain sedimentation alone.

The two sets of analyses which show the progressive removal of suspended and organic matters by the four basins further indicate that the suspended mat-

ter in the Canton sewage after lime treatment, is deposited under a very short period of flow and that the third and fourth basins at least afford little material gain in efficiency. Except that they are of service when sludge is removed from the tanks since they allow the process of sedimentation to continue with practically no decrease in efficiency, their presence does not especially increase the removal of suspended matter.

TABLE NO. 15.

Removal of Organic and Suspended Matter During Detailed Examinations.

Date of Examination.	Parts Per Million.								Percentage Removal.			
	Oxygen Consumed.		Organic Nitrogen.		Suspended Matter.				Oxygen Consumed.	Organic Nitrogen.	Suspended Matter.	
					Total.		Volatile.					
	Sew.	Eff.	Sew.	Eff.	Sew.	Eff.	Sew.	Eff.			Total.	Volatile.
August 9–10, 1906	54	24	6.9	6.9	43	42	31	30	54	18	2	3
January 16, 1907.	40	32	17.0	10.1	83	41	42	29	20	40	51	31
February 26, 1907	101	49	18.2	7.9	124	61	62	28	52	57	51	55
July 17, 1907....	34	23	13.6	6.8	89	51	47	40	33	50	45	17
July 18, 1907....	38	18	12.8	4.8	118	58	65	30	53	63	51	54

Amount of Sludge Produced. As already stated, conditions with regard to sludge disposal render it impracticable to compute from the sludge data, as reported at the plant, the approximate original deposition. From the analytical data obtained on Feb. 26 and July 17, 1907, however, it is possible to obtain a rough approximation of the amount of sludge actually deposited on this basis. The deposition of sludge on July 17, 1907, during the application of lime was 0.26 ton per million gallons. The quantity deposited on Feb. 26, when the application of lime had ceased for the winter, was 0.27 ton per million gallons. It is to be noted that the suspended matters in the raw sewage were practically the same in each case.

Results of Final Inspection. The Canton plant was again visited on November 1, 1907, when conditions were found to be practically the same as on previous visits. The sludge area had recently been plowed, but on account of the large quantity of sludge produced at the plant, the area is practically inadequate as the entire available acreage is ponded with dried and semi-dried sludge. There has been apparently very little complaint of odors from drying sludge during the summer and fall of 1907.

SUMMARY.

Reviewing the data obtained during this investigation it is apparent that the Canton sewage plant removes about 50 per cent. of the organic matters in the crude sewage, but produces an effluent which is uniformly of unstable nature, such that the stream into which the effluent flows suffers considerable pollution. The polluting effect of the imperfectly purified sewage of Canton is, however, materially alleviated by the presence for a greater part of the time of consid-

erable quantities of iron pickling liquors discharged from one of the large manufacturing establishments in the city.

On account of the rapidly increasing population of Canton, especially in view of a sludge nuisance which will no doubt become more and more serious each year, this investigation has shown that the present plant has practically reached its capacity for operation on a chemical precipitation basis and that in the near future steps will be necessary to enlarge the plant and to place the purification of the sewage of the city on a more modern footing. It is important furthermore, that a plant to provide for the future growth of the city shall include the purification of the sewage to a non-putrescible state. The results of this investigation, moreover, point to the strong advisability of discontinuing the use of lime since it has been found that practically as well clarified effluents may be obtained by plain sedimentation alone.

COSTS.

The cost of construction of the Canton sewage plant was $31,545, which includes $5,000, the cost of the land.

The cost of operation has varied but little from year to year. The total operating expenses for the years 1904 to 1907, inclusive, were $3,369, $3,131, $3,802 and $3,200, respectively. It has not been possible to obtain an itemized statement of the several items which comprise the above operating expenses. The labor item is about $2,000 per annum and includes the salaries of three engineers at $65, $50 and $50 per month, respectively. The annual operating costs for the years 1906 and 1907 correspond, respectively, to 16 cents and 14 cents per person tributary to the sanitary sewers.

TABLE NO. 16.

Results of Chemical Analyses.

Basin No.	Date 1906-'07.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.														
				Oxygen Consumed.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.
						Organic.		Free Ammonia.	Nitrites.	Nitrates.							
				Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.				
				Crude Sewage.													
....	Aug. 9, 1906	6:00 A.-10:00 P.	64	57	30	7.3	4.1	8.5	0.00	0.0	29	48	36	74	.....	....	22
....	August 9-10	10:30 P.- 6:00 A.	64	47	16	6.0	2.8	5.0	0.02	....	18	33	21	14	.....	....	11
	Weighted Average....	.....	64	54	24	6.9	3.7	7.3	0.01	0.0	25	43	31	54	.....	....	17
....	Jan. 16, 1907	7:00 A.- 9:00 P.	52	40	.....	16.9	.....	11.0	.....	....	....	.....	....	....	.....	....	....
....	Feb. 26, 1907	7:00 A.- 9:00 P.	50	101	54	18.2	7.9	12.0	0.07	0.0	46	124	62	....	.....	....	32
....	July 17, 1907	7:00 A.-11:30 P.	65	34	24	13.6	5.6	10.4	0.00	0.0	54	89	47	30	.....	....	....
....	July 17-18, 1907	12 Mid.- 6:30 A.	63	11	9	6.8	2.8	5.2	0.13	0.0	25	51	40	26	.....	....	....
	Weighted Average....	.....	64	26	19	11.3	4.7	8.7	0.04	0.0	44	76	45	29	.....	....	....
....	July 18, 1907	7:00 A.- 5:00 P.	66	38	28	12.8	5.6	12.0	0.02	0.0	81	118	65	48	0.0	....	....

Effluent Settling Basins.

4	Aug. 9-10, 1906	10:00 A.- 2:00 P.	66	27	20	7.0	3.8	8.0	0.00	0.0	....	44	32	4	.....	+	....
4	Aug. 9-10, 1906	2:30 A.- 9:30 A.	65	17	13	3.0	1.8	6.0	0.00	0.0	....	39	26	0	.....	+	....
1	Jan. 16, 1907	7:00 A.- 9:00 P.	52	37	.....	17.3	.....	8.2	.....	....	....	45	22	....	.....	+	....
2	Jan. 16, 1907	7:00 A.- 9:00 P.	51	36	.....	12.7	.....	8.0	.....	....	....	51	29	....	.....	+	....
3	Jan. 16, 1907	7:00 A.- 9:00 P.	50	33	.....	12.9	.....	7.0	.....	....	....	49	33	....	.....	+	....
4	Jan. 16, 1907	7:00 A.- 9:00 P.	50	32	.....	10.1	.....	6.6	.....	....	....	51	31	....	.....	+	....
1	Feb. 26, 1907	7:00 A.- 9:00 P.	49	68	.....	11.9	.....	12.0	.16	....	44	72	33	....	0.0	+	....
2	Feb. 26, 1907	7:00 A.- 9:00 P.	49	52	.....	11.9	.....	12.0	.05	....	39	74	35	....	0.0	+	....
3	Feb. 26, 1907	7:30 A.- 9:30 P.	49	52	.....	7.9	.....	12.0	.06	....	42	67	29	....	0.0	+	....
4	Feb. 26, 1907	7:30 A.- 9:30 P.	49	49	.....	7.9	.....	12.0	.09	....	38	61	28	....	0.0	+	....
1	July 17, 1907	7:00 A.- 5:00 P.	65	30	.....	11.6	.....	14.0	0.00	0.0	....	85	50	....	0.0	+	....
2	July 17, 1907	7:00 A.- 5:00 P.	65	26	.....	8.4	.....	10.8	0.00	0.0	....	50	24	....	0.0	+	....
3	July 17, 1907	7:00 A.- 5:00 P.	66	24	.....	6.4	.....	9.6	0.35	0.0	....	47	37	....	0.0	+	....
4	July 17, 1907	7:00 A.- 5:00 P.	66	23	.....	6.8	.....	13.2	0.00	0.0	....	49	38	....	0.0	+	....
1	July 18, 1907	7:00 A.- 5:00 P.	66	28	.....	9.2	.....	10.0	0.10	0.0	....	115	51	....	0.0	+	....
2	July 18, 1907	7:00 A.- 5:00 P.	67	24	.....	7.6	.....	8.4	0.17	0.0	....	59	28	....	0.0	+	....
3	July 18, 1907	7:00 A.- 5:00 P.	67	19	.....	5.6	.....	8.8	0.13	0.0	....	55	39	....	0.0	+	....
4	July 18, 1907	7:00 A.- 5:00 P.	68	18	.....	4.8	.....	9.6	0.00	0.0	....	58	30	....	0.8	+	....

CLYDE.

The village of Clyde is in Sandusky County on Raccoon Creek, a small stream with little or no dry weather flow. The creek eventually flows into Sandusky Bay. The village is in a rich farming country and lies at the foot of a valley of considerable area so that it forms practically a drainage basin for the surrounding territory. Aside from its agricultural advantages, the village supports a number of industries which include a granite works and the manufacture of sauerkraut, automobiles, cooperage and signs. Village improvements consist of about 1.6 miles of brick pavement and a system of sewers on the combined plan. A public water supply was installed in 1884 and comprises a system of driven wells from which there is pumped daily about 220,000 gallons, according to the village waterworks records for 1906.

SEWERAGE.

The first sewers were constructed in Clyde in the year 1893 and were chiefly for the removal of storm water. Subsequently the system was enlarged for the reception of the sanitary wastes of the village and at the end of 1907 comprised about 4.0 miles of pipe sewers. The sewers lead to the county pike, where arrangements are made to convey the dry weather sewage flow to a purification plant through a new 12-inch pipe sewer constructed for this purpose in 1898. The excess of storm water is caused to flow into the old storm water sewer which has existed on the pike since about the year 1893. It has an outlet into Raccoon Creek just above the sewage purification plant.

The present sewers of Clyde are on the combined plan and during storms receive a large quantity of storm water, especially in view of the location of the village. They at all times carry a large quantity of ground water. The ground water leakage at Clyde is perhaps more pronounced than that at any other plant in the state. Roof water is also a feature of storm flows, as a large number of eve troughs are connected to the sewers. Perhaps due to the unusually large flow, it has not been necessary to operate the eight flush tanks provided in the original design of the sewerage system. Since the year 1905, practically no manufacturing wastes have reached the Clyde sewers. Formerly the pressed juices from two kraut factories were discharged into the sewers to the great detriment of the sewage purification plant, but in the year 1905 this practice was enjoined by the courts and ceased forthwith.

Of the 2,800 persons in Clyde, as estimated from the census reports, about 1,050, or 38 per cent., are connected to the sewers for sanitary purposes. The total number of sanitary connections is 229, according to information obtained from the village clerk.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In 1898, five years after the first sewers were built in Clyde, certain farmers owning land along Raccoon Creek below the village brought suit against the corporation because of a nuisance alleged to be caused by the discharge of sewage in a raw state. To prevent the filing of further suits and to provide for a more satisfactory disposal of the sewage of the village than its discharge into a stream of intermittent flow, a sewage purification plant was built in 1898. This plant comprises about 2.7 acres of intermittent filters which receive crude sewage with but slight preparatory treatment. Plans for this plant were sub-

mitted to the State Board of Health and were approved in September, 1898, with advice as to the change of certain details of the design and also with the reservation of the right to order such extensions of the system as might be shown to be desirable after the plans were carried out, if the purification of the sewage was not satisfactorily effected.

EXAMINATIONS AND INSPECTIONS.

Visits were made to Clyde in 1906, on April 24, June 1-3 and Dec. 4-5; in 1907 on Feb. 13, May 16-17 and Oct. 23. Detailed examinations were made on the second, third and fifth visits.

DESCRIPTION OF PLANT.

The site of the Clyde sewage plant comprises 25 acres of land owned by the village and located about one-half a mile northwest of a main part of the thickly settled district. There are three houses about 800 feet distant and one 500 feet distant. The crude sewage without preliminary screening and with but a brief period of sedimentation flows directly on to the 2.7 acres which are prepared for sewage purification. (See Plate XXIV.)

FILTERS.

The Clyde filtration area comprises six units constructed from the natural soil. Five of the areas range from 0.22 to 0.41 acre in area, and one unit for winter usually known as the "Big Pond" has an area of 44,000 square feet or 1.01 acres. The total area is 2.70 acres. The area is divided into six units by earth embankments.

Filtering Material. The filtering material, which is the natural soil, consists of fine clayey sand, with an effective size of 0.03 m. m. and a uniformity coefficient of 6.0. The filters were prepared by stripping, grading and underdraining the soil at a depth of 4 feet.

Underdrains. The underdrains comprise main lines of 12-inch vitrified pipe. The laterals are 4-inch agricultural tile laid with butted joints and placed 16 feet apart. At the end of each main drain lantern holes are provided, consisting of 8-inch vertical pipes, which extend about 10 inches above the surface of the filters. Besides serving for ventilating purposes, these pipes prevent serious flooding of the plant in times of high water, as they afford a means for the escape of the excess of sewage flow. No coarse material is used in the trenches which contain the underdrain tile.

Distribution Devices. No special devices are provided for dosing the filters and the crude sewage flows directly from the main carrier. This main carrier is an extension of the 12-inch main sewer and at intervals to allow of the diverting of the sewage to the different filters, is provided with brick gate chambers containing iron shear gates.

No means are provided for the distribution of the sewage on the filters themselves, and the sewage discharges at one corner into a shallow box, which for convenience has been termed a sludge box. These sludge boxes, which afford the only preparatory treatment of the crude Clyde sewage, vary in size and range from 9 feet 7 inches by 12 feet in plan and 12 inches deep to 7 feet 6 inches by 16 feet in plan and 12 inches deep. They are constructed of wood and are not baffled. Sewage overflows on the sides of the boxes when considerable material has accumulated, but when clean through holes provided in the end and at the bottom. From these boxes the sewage flows directly on to the filters. In addi-

tion to these sludge boxes, some sedimentation is afforded by the gate chambers. The relative location of the sludge boxes and filters and the general arrangement of the plant may be noted by referring to Plate XXIV.

Effluent Discharge. There are two 12-inch outlets, one provided for the large one-acre filter and one for the five smaller filters. The effluent from the filters discharges by gravity. The embankments surrounding the plant serve in part for a protection against floods, but during excessive floods the entire plant is submerged.

SEWAGE FLOW.

The quantity of crude sewage reaching the Clyde plant is, of course, entirely dependent upon weather conditions since the sewers are on the combined plan and since they practically serve to drain the higher land adjacent to Clyde. On this account, measurements obtained on the three detailed examinations of the plant have shown considerable variation. Although in all cases these detailed tests were carried out for periods of 24 hours, during which no rain fell, yet the elevation of the ground water was different on each visit and consequently the proportionate quantity of ground water in the sewage varied.

On the first detailed examination the quantity of crude sewage ranged from a maximum of 270,000 gallons to a minimum of 120,000 gallons and averaged 172,000 gallons in 24 hours. On the second examination on Dec. 4, 1906, the average, maximum and minimum flows were, respectively, at rates of 288,000, 329,000 and 151,000 gallons. These measurements extended only from 6:00 o'clock A. M. to 10:00 o'clock P. M. On the detailed examination of May 15-17, 1907, the average rate of flow was 302,000, the maximum 360,000 and the minimum 244,000 gallons in 24 hours. These measurements were continued for 24 hours and showed a maximum flow at 9:00 o'clock A. M. and a minimum flow practically from 11:30 o'clock P. M. until 5:30 o'clock A. M.

Expressing the sewage flow of Clyde on the basis of gallons per person tributary, the results obtained during the three detailed examinations of the plant indicate flows per person connected of 163, 274 and 287 gallons, respectively. The corresponding water consumption of the village, as before stated, about 220,000 gallons daily, or 101 gallons per person using (1906). As only 38 per cent. of the total population is connected to the sewers, it is evident that the ground water present in the Clyde sewage forms a very large percentage of the total flow.

COMPOSITION OF CRUDE SEWAGE.

In view of the entrance into the sewers of such large quantities of ground water, it is apparent that, generally speaking, the crude sewage of Clyde is very dilute. The analytical data obtained during this investigation, which include the analysis of samples of the crude sewage collected on the three detailed examinations made at Clyde, point decidedly to the unusually high dilution sustained by the Clyde sewage. Since the kraut juices have been withdrawn from the Clyde sewers, according to analytical evidence obtained during this investigation, the crude sewage of the village is strictly domestic in character. The presence of ground water causes the sewage to be well oxygenated at all times, as shown by the presence of dissolved oxygen, nitrogen as nitrites and nitrates. Another striking feature, also attributable, it is thought, to the high dilution of the sewage, is the fact that the greater part of the organic matters are in suspension and are granular in form so that a short period of subsidence tends to remove them in large part. This feature, no doubt, explains the efficiency of the sludge boxes to which the sewage is applied before it reaches the sand filters themselves. In

appearance the sewage is generally clear and shows practically no evidence of colloidal matter.

OPERATION.

In the preliminary inspection at Clyde on April 24, 1906, it was found that for some time past it has been the local practice to operate the filters continuously, that is on a water filter basis. The officials stated that one unit is in use for four days, following which a second filter is placed in service. Four days were stated to be required for a filter to drain.

On the first detailed examination of the plant, however, it was learned that at times the filters are allowed to remain in service for weeks at a time, or until the sewage can no longer freely pass through the sand. Subsequent visits have shown that the continuous use of one filter is the general successful method employed at this plant.

During the winter months, generally from December 15th to April 15th, the "Big Pond" is alone used. This pond has an area of 1.01 acres and according to the average sewage flow it is continuously operated at rates which range from about 170,000 to 300,000 gallons per acre in 24 hours, a rate which is, of course, largely increased during storms and long continued wet weather. The rate of filtration for the remaining area ranges from 110,000 to 195,000 gallons per acre in 24 hours. The population tributary per acre for the entire plant is 390.

In 1906, the filters were cleaned twice and the method consisted in removing the mat of suspended matter, following which the filters were plowed, harrowed and leveled. In 1907, the filters were cleaned but once by a new method devised by the village official in charge as follows: The filters are first plowed without the removal of suspended matters and are then planked with a device which comprises three 2-inch planks 12 feet long cleated together and arranged so that they may be dragged over the filter by horses. Following this treatment a so-called scraper is used to level all rough surfaces. It is further necessary to remove all vegetation, which in 1906 was done by hand, but in 1907 by a mowing machine. The new method of cleaning the entire area is stated to cost about $29.00, as against $58.00 with the old process, or $10.75 and $21.50 per acre, respectively. A study of the plant by the officials in charge is stated to have shown that it is not necessary to remove the accumulated surface mat, provided it is first allowed to dry, since it is of a granular nature and permits the fairly free passage of the sewage. In addition to the attention required for changing the filters in service, from time to time it is necessary at intervals of from two to three weeks to clean the sludge boxes and gate chambers, which in view of the peculiar local sewage rapidly become filled with sludge.

So far as may be judged from information available from the several visits to this plant, it appears that except during extreme wet weather when the dilution afforded by Raccoon Creek is probably sufficient to allow the disposal of the crude sewage by dilution alone, all of the sewage of the village is passed through the purification plant.

EFFICIENCY.

In discussing the efficiency of the Clyde sewage purification plant, it is first of interest to recall briefly the unsuccessful effort to purify the sewage of the village when the juices from the manufacture of kraut were allowed to enter the sewers. These experiences are fully described in the special report of the State Board of Health for the year 1903. Shortly after the plant was built, during the fall when sauer-kraut was being manufactured the wastes which are said to have ranged in quantity from 2,000 to 9,000 gallons a day were di-

rectly discharged into the sewers and were received for treatment at the purification plant. Analyses of the waste showed that it was exceedingly high in organic matter and in view of the continuous method of operation carried out at the plant, it is not surprising that very unsatisfactory results were obtained. On all inspections it was found that the effluent had a strong odor, and was in such an unstable condition that it caused foul deposits along the banks of Raccoon Creek. The failure of the plant to dispose of the sewage of the village without a nuisance led to filing of suits against the corporation, which in turn sought through the courts to restrain the kraut company from the use of its sewers for the disposal of the by-products of the manufacture of sauer-kraut. This suit was won by the village and since the year 1905, the kraut wastes have been discharged into two 10-inch wells said to be 90 feet deep whereby the juices are caused to mingle with the considerable quantity of ground water found in Clyde and vicinity.

The detailed examination of this plant carried out on June 1-3, 1906, showed that the effluent from the filters was non-putrescible, as it was well protected by dissolved oxygen and nitrates. The efficiency of the plant was in general high and as compared with the usual practice this high efficiency from continuously operated sewage filters seemed surprising. The analyses of the crude sewage, however, showed such a large dilution with ground water and the continued presence of dissolved oxygen and nitrates, that these facts together with the granular character of the suspended matter seemed to be a satisfactory explanation of the success of the peculiar local methods of operation.

This examination also brought out the fact that the sludge boxes located in the corners of three of the filters, in a large part protect the main portions of the filtering material from rapid clogging, and consequently the village authorities were advised to construct similar boxes for all the filters. It was suggested also that the plant be given better supervision.

On the next visit made on December 4-5, 1906, it was found that the filters had all been equipped with sludge boxes, that the plant was receiving greater supervision and that in general its appearance had greatly improved. Further evidence was also obtained as to the efficiency of the gate chambers and sludge boxes in removing suspended matter from the Clyde sewage. It is to be stated, however, that at times when the boxes need cleaning, removal of the suspended matters is very low, but in general, as an inspection of the plant will show, they are of considerable service in removing suspended matter from the crude sewage.

Further data were obtained regarding the presence in the sewage of dissolved oxygen and nitrates. On the whole the plant was found to be in a very satisfactory condition and was purifying the sewage of the village without a nuisance. On the winter visit on Feb. 13, it was found that the plant was bypassed, on account of heavy rains in January for a period of five days, following which the sewage was again applied to the "Big Pond." There appeared to be no particular difficulty in operating the "Big Pond" on a continuous basis. When inspected it had been in service for about two months and the surface of the filtering material was covered with an algal sludge blanket, but apparently the purified sewage reached the underdrains without undue difficulty. The temperature of the sewage was 46 degrees F. Although cold weather had obtained for several days previous, it apparently did not materially effect the operation of the plant. About three-fourths of the surface of the "Big Pond" was covered with a coating of ice. While the sludge pits required cleaning, it was again brought out strongly that these small settling basins are important features in the operation of this plant on a continuous basis, since they tend to preclude the septicization of the surface layers of the filters. The effluent from the "Big Pond" on this inspection was fairly well purified, it possessed no odor and was

of fairly low turbidity. The remaining filters were out of service, but had been cleaned in the fall and were ready for use in the spring.

Interesting information was obtained on the detailed examination of May 16-17, 1907. The "Big Pond" in use since about December 1st, 1906, was not entirely uncovered, permitting samples to be collected of the effluent. Analyses of these samples showed a remarkably well purified effluent, containing 2.0 parts per million of nitrogen as nitrates, 6.9 parts per million of dissolved oxygen and only 4.0 parts per million of oxygen consumed. The full analysis of this sample will be found at the close of this report on Clyde. On inspection, it was found that the coating of suspended matter on the surface of the "Big Pond" was from 1 to 3 inches in thickness. An interesting series of dissolved oxygen data were obtained as illustrating one of the peculiar features of the Clyde crude sewage. These data are tabulated as follows:

TABLE NO. 17.

Dissolved Oxygen in Crude Clyde Sewage.

Hour — May 16-17, 1907.	Parts Per Million.
10:00 A. M.	1.5
12:00 M.	4.7
4:00 P. M.	4.5
8.00 "	3.2
12:00 "	4.1
4:00 A. M.	5.3

The general appearance of the plant was good and the effluent from the filter in service was satisfactory as reference to the analytical data will indicate.

The final inspection of this plant took place on Oct. 23, 1907. The plant was found to be in excellent condition and was producing a clear non-putrescible effluent.

SUMMARY.

The conclusions to be drawn from the analytical evidence obtained during the visits to the Clyde sewage purification plant are that it serves very satisfactorily to purify the sewage of the village. Since the kraut wastes have been withdrawn from the sewers, the plant has at all times afforded an effluent of satisfactory quality and since 1905 no suits have been lodged against the village on account of alleged nuisances caused by the sewage plant. The appearance of the plant has been greatly improved as a result of this investigation, due to the greater supervision it has received, and to the constructional changes suggested by the State Board of Health. Attention and care given the plant on the part of the village officials in charge, deserves special mention as the plant is an example of what marked improvements may be effected when it is under the eye of an interested official. The peculiar local conditions at Clyde with respect to the dilute character of the crude sewage are again deserving of special comment, in view of the operation of the plant on a water filter basis, a practice which is probably of rare successful application with plants of the intermittent sand filter type.

In conclusion, acknowledgement is made of the valuable assistance rendered by the Clyde officials during visits to the plant.

DESCRIPTION OF PLANT.

The plant for the purification of the Glenville sewage was completed in May, 1899. Only about one-half of the filter area shown by the plans was constructed, and due to some cause a sand of very poor quality was used for the sand filters. The plant is located on a 14-acre tract of land owned by the city and situated in the valley of Dugway Brook, adjacent to the Lake Shore & Michigan Southern Railroad tracks, and about 500 feet east of the edge of the thickly built up portion of the city. When constructed, the nearest house was about 1200 feet distant, but at the present time (1907), a number of dwellings have been built 150 feet from the chemical precipitation tanks. The plant, as constructed, comprises a two-story brick building, which contains accessories for chemical treatment, four chemical precipitation tanks, 0.372-acre coke strainers, and 1.0-acre intermittent sand filters.

Power Plant.

The apparatus for preparing and applying the chemicals is contained in a two-story brick building about 35 feet square; the second story is accessible by a driveway. The lower floor is used as a boiler room, for the application of chemicals and contains the sludge pump. Through the center of the lower floor there is a channel which is an extension of the main sewer and in which milk of lime is introduced into the sewage.

Steam for pumping sludge and for sludge pressing (now abandoned) is furnished by a 40-H. P. horizontal tubular boiler. The proper mixing of the lime solution is maintained by stirring devices operated by a 12-H. P. vertical engine.

Apparatus for Applying Chemicals.

The milk of lime is first prepared in a wooden slaking tank, 3.0x7 feet 4 inches in plan and 2.0 feet deep and of 300 gallons capacity. The tank is located on the second floor of the power house and from it the lime solution flows by gravity through an opening in the bottom, controlled by a plug.

The solution tank proper is on the ground floor of the power house and is a steel tank 5 feet in diameter and 6 feet high, 5 feet in depth to the flow line and of about 730 gallons capacity. The strong milk of lime solution flows from this tank through a 1½-inch iron pipe controlled by an ordinary gate valve. The stirring devices contained in the solution tank comprise rotating arms operated by belt-driven shaft, worm gears, and rack, which reduce the shaft revolutions from 60 to 14.4 R. P. M.

The bulk lime obtained in barrels is stored in the upper floor of the power house.

Screens.

The crude sewage is first screened through iron strips ¼x1½ inches in cross section, spaced with a clear opening of ½ inch. The entire screen is 5 feet 6 inches long and 4 feet wide, and has an area of 22 square feet. The screen is inclined about 70 degrees to the vertical, and at its upper end there is a wooden shelf upon which the screenings may be raked for ready removal. The 6-foot inlet channel serves virtually as a screen chamber.

Grit Chamber.

While no grit chambers were provided in the original design, the inlet channels of the chemical precipitation tanks serve to arrest considerable fine quicksand and recently (1907) baffles have been introduced to facilitate the deposition of the heavier mineral matter.

Chemical Precipitation Tanks.

The chemically precipitated sewage passes into the chemical precipitation tanks, which are four in number, and are 30x30 feet in plan and 7 feet deep; the depth to the flow line ranges from 6 feet 7 inches to 7 feet. The capacity of each tank is about 46,000 gallons, and the total tank capacity is 184,000 gallons. The tanks are constructed of brick plastered with mortar and capped with 3-inch stone. The end walls are 30 inches thick and the dividing walls 36 inches thick. The bottom of the tank is constructed of 12-inch concrete. The tanks are uncovered.

Inlets and Outlets. The inlet channel, 3 feet wide and 2 feet deep, surrounds the four tanks on three sides. The inlets proper comprise 4-foot openings, one leads from the inlet channel and two from or into adjacent tanks. The outlets are arranged similarly, in fact any given inlet may be used as an outlet. The outlets and inlets are controlled by 3 x 4-foot stop planks of 2-inch lumber.

Baffles. The individual tanks are not baffled, but the stop planks may serve in part as surface baffles to retain floating material and grease and to prevent their passage from one tank to the next.

Sludge Drains. There is one central sludge drain, 12 inches wide and 6 inches deep and it extends lengthwise through the center of each tank. The floor of the tanks slopes from the farthest tank towards the sludge well. Each individual tank is 5 inches deeper at the center than on the sides.

By-pass. At the end of the inlet channel is a 3 x 4 foot flash board, which may be raised and thus permit the discharge of the entire sewage flow without treatment.

Aerating Channel and Measuring Weirs. No special means are provided for the aeration of the chemically precipitated and settled sewage, and no special permanent means for weiring the sewage flow.

Effluent Discharge. The effluent is discharged from the tanks through an 8-inch hinged floating outlet pipe which leads to an effluent sewer and thence onto the coke strainers.

Sludge Disposal Area.

The sludge flows to a brick sludge well 12 feet in diameter and 18 feet deep of 15,000 gallons capacity. Several acres of low land on the site of the plant are available for the disposal of the sludge. To reach this land it is necessary to pump the sludge, and in the original layout sludge pumping was also necessary as a 50-compartment filter press was formerly used. In recent years, sludge has been pumped through some 1,500 feet of 2-inch iron pipe.

The sludge pump is a duplex steam pump with cylinders 10 x 6 x 12 inches with a 4-inch suction and a 3-inch discharge provided with 5-inch hard rubber ball valves set in cups. The pump is especially designed for handling sludge and raises it from 10 to 20 feet.

Coke Strainers.

For some time past the contact filters have been operated as rough strainers. They comprise two areas, each 64 x 127 feet, or 0.186 acre, and a total area of 0.372 acre. The strainers are surrounded and separated by earth embankments.

Filtering Material. The filters are constructed of coke and gravel to a total depth of 3 feet. The lower 2 feet is constructed of fine coke breeze which is surmounted by 12 inches of gravel which has an effective size of 1.1 m. m. and a uniformity coefficient of 4.0.

Underdrains. The strainers are underdrained by a 20-inch main drain of vitrified sewer pipe, from which branch 6-inch laterals laid 8 feet apart. There

are no lantern holes nor other means of ventilation. The underdrains are covered with large pieces of coke.

Dosing and Distribution Devices. The coke strainers receive the direct flow from the sedimentation tanks on a continuous basis. To distribute the sewage there are eight points of discharge located on one side of each tank. To concentrate the deposition of suspended matter, shallow basins have recently (1906) been formed by means of a 3-inch plank 2 feet wide embedded 18 inches in the material at a distance of 5 feet from the side of each strainer. The basins thus formed are roughly 6 inches deep and extend the full length of the strainers.

Effluent Discharge. The effluent from the strainers flows by gravity onto the sand filters.

FILTERS.

The sand filters as now in service, comprise four filters each with an area of 0.25 acre, and located about 300 feet from the coke strainers. The filters are separated and surrounded by seeded earth embankments formed from the original excavation.

Filtering Material. The filtering material 36 inches in depth consists of a very fine clayey sand with an effective size of 0.09 m. m. and uniformity coefficient of 2.9. Extending to the underdrains, sanded trenches 20 inches wide and 10 inches apart were constructed in 1906. They contain coarse sand which has an effective size of 0.29 m. m. anud a uniformity coefficient of 2.9.

Underdrains. The underdrainage system comprises lateral lines of 4-inch vitrified sewer pipe with bells and spigots, and laid with open joints. The lateral lines are 10 feet apart. There are no lantern holes nor other means of ventilation.

Dosing Devices. The sand filters receive the direct flow from the coke strainers, or from the chemical precipitation tanks in case the coke strainers are temporarily out of service.

Distribution Devices. Gate chambers containing 20-inch iron shear gates operated by rods, control the flow onto the four filters. The sewage from a given gate chamber flows onto the filter proper through 6-inch pipes 15 feet apart located on the side of a filter; these pipes discharge practically flush with the surface of the filtering material. No further nor more thorough means is provided for distributing the sewage.

Effluent Discharge. The effluent from the sand filters flows by gravity through approximately 750 feet of 20-inch vitrified sewer pipe to Dugway Brook. The plant is so located with respect to the elevation of the brook that no trouble has been experienced in regard to the flooding of the plant in times of high water.

SEWAGE FLOW.

During this investigation, records of the sewage flow at this plant were obtained only on the detailed examination carried out in July, 1907. These gagings were made under dry weather conditions and comprised half hourly weir measurements from 7:00 o'clock A. M. to 11:00 o'clock P. M. No measurements were made during the night as it was thought that the flow at that time would correspond closely to that at 7:00 o'clock A. M. It was noticeable that during the hours the measurements were made, the range in the rate of flow was only from 1,115,000 to 1,400,000 gallons, a feature which suggests that considerable ground water enters the Glenville sewers. With the assumption of slightly reduced flow after 11:00 o'clock P. M. the total flow on the visit of July 9th, 1907, averaged 1,200,000 gallons in 24 hours, or about 185 gallons per person tributary. Observations of the sewage flow during wet weather have, of course, shown much larger volumes of sewage than the above.

COMPOSITION OF CRUDE SEWAGE.

The single detailed examination at Glenville indicated that the crude sewage is essentially domestic and contains at times a considerable proportion of ground water. Although the sanitary wastes of Glenville were planned to be removed by a separate system of sewers, yet it appears that large volumes of storm water reach the sanitary sewers. One of the most interesting features in this connection is the large quantity of quicksand which is generally carried by the crude sewage. The full analysis of the crude Glenville sewage follows this section of the report.

OPERATION.

Up to October 15, 1907, the Glenville plant has been operated by two men who are on duty for nine hours from about 7:00 o'clock A. M. The operation of the plant has been under the general supervision of the Cleveland Engineering Department. Extra labor has been used when occasion required. The plant was abandoned on October 15th, 1907, when the Glenville sewage was directed into the intercepting sewers of Cleveland.

Screens.

The screens at Glenville intercept considerable material, said to comprise about one wheelbarrow load daily. It is necessary to rake the screens at frequent intervals. The screenings are wheeled to a dumping ground and are buried. The accumulated screenings are of objectionable appearance, but no odors are noticeable.

Application of Milk of Lime.

Lime treatment at this plant has consisted in the use of 500 pounds daily up to July 15th, 1907. The application of lime begins at 7:00 o'clock A. M. and the quantity applied is intended to be sufficient for a period of 8 hours. Irregularities in the flow from the solution tanks are at times such that all of the lime has been applied by 2:00 o'clock P. M. Although the sewage flow is generally increased during rains, the quantity of lime applied is not changed, and during especially heavy rainfall the sewage is by-passed without treatment.

Slaking. In preparing the milk of lime, that quantity necessary for an 8-hour run is shoveled into the slaking tank, covered with cold water and allowed to stand for about 20 hours. The unslaked lime used was found on analysis to contain about 62 per cent. available calcium oxide (CaO).

Quantity Applied. The valve on the 1½-inch wrought iron line from the lime solution tank readily clogs and causes great irregularity in the rate at which the milk of lime is applied. On the assumption that the sewage is treated with lime for eight hours daily and on the basis of the average flow as found in July, 1907, the quantity of lime applied to the sewage will average 8.8 grains per gallon. An average sample of the milk of lime was found on analysis to contain .332 grains available calcium oxide per gallon.

On July 15th, 1907, the lime treatment was discontinued.

Sedimentation Basins.

After screening and lime treatment, the sewage flows directly into the four settling basins, which are generally operated in series. With the average rate of sewage flow, the period of flow through the tanks is about 3.7 hours.

Ordinarily, one tank is out of service for cleaning every other day. In cleaning, the supernatant sewage is drawn off through the floating outlet. When the supernatant sewage has been almost removed, the last part is diverted to the

sludge well whence it is pumped back to the first settling tank. The sludge itself is then allowed to enter the well. In part, it flows by gravity, but a considerable part is scraped or pushed into the central sludge drain with rubber bottomed pushers.

Sludge Disposal.

From the sludge well, the sludge is pumped by the Hughes sludge pump with special rubber ball valves through some 1,500 feet of 2-inch black iron pipe onto low land adjacent to the plant and for the greater part lying near the outlet of the plant on the banks of Dugway Brook.

As it is the practice to clean one tank every other day, the tank first to receive the lime treated sewage is varied. On July 9th, a tank was cleaned which had been in service for three days. The quantity of sludge deposited was estimated at roughly 29 cubic yards and on the basis of a sewage flow of 1,200,000 gallons in 24 hours, the three days' operation caused an accumulation of wet sludge to the extent of about 7.5 cubic yards per million gallons.

The sludge pumped from the well receives no further treatment.

Coke Strainers.

For some time past, the operation of the coke filters on the fill-and-draw basis has been discontinued, owing largely to the greatly increased flow of sewage. The coke filters have therefore been operated merely as high rate strainers. Under present conditions, the strainers which are used on alternate days operate at an actual rate of 6,500,000 gallons and a net rate of 3,250,000 gallons per acre for 24 hours. The shallow basin formed along the side of each strainer in the summer of 1906, materially protects the main body of the filtering material from clogging, but ordinarily, about 75 per cent. of the total area of each strainer is submerged at the end of a day's run. In 1906, the upper surface of the coke filters was cleaned, and in case of one of the filters the upper foot was removed and replaced with clean gravel.

Sand Filters.

For some years, up to the summer of 1906, no attempt was made to operate the finishing filters at the Glenville sewage plant. Early in the history of the plant they proved to be a failure chiefly on account of the character of the sand in conjunction with the greatly increased flow of sewage. In the summer of 1906, the Cleveland Engineering Department made an effort to reoperate the sand filters especially as it seemed practicable to obtain information as to the feasibility of operating sandy areas of fine grained material containing trenches of coarse sand well underdrained. Accordingly, trenches, already described, were prepared and the underdrains were relaid with vitrified pipe.

The filters were operated intermittently and for a few weeks passed the applied coke strainer effluent without difficulty; subsequently, the filters clogged to such an extent that the coke strainer effluent could not be filtered at all. During December, 1906, the underdrains in one of the units were uncovered and it was found that in the absence of coarse material directly over the tile, the sockets had become filled with sand and the entire drainage system had become practically impervious to water. The tile in all the filters were then dug up, relaid with more open joints and covered to a depth of 1 inch with coarse cinders before replacing the sand. On December 19th, 1906, two filters were in service during the day and night, respectively. On the visit of July 9th, 1907, a similar practice prevailed. The gates controlling the flooding of the filters were said to be changed at 7:00 o'clock A. M. and 5:00 o'clock P. M. From the average flow at this time, the average rate of operation attempted was 1,200,000 gallons, correspond-

ing to an actual rate of 2,400,000 gallons. The sand filters could not be successfully operated and were out of service for cleaning at frequent intervals.

EFFICIENCY.

The Glenville sewage plant is an interesting example of the inadequacy of chemical treatment in disposing of the sewage of a city without offense. In addition to these interesting data, valuable experiences have been noted as to the subsequent treatment of settled sewage and the feasibility of operating filters of fine grained material trenched with coarse material well underdrained.

Chemical Precipitation.

A few data are available as to the efficiency of the settling tanks and chemical treatment. Average samples collected for about 15 hours on July 9th, 1907, indicated that the actual efficiency of the basins was very low. The average suspended matter in the crude day sewage was only about 80 parts and that of the effluent was 50 parts per million. Corresponding slight reductions were also noted in the other constituents as reference to the appended analytical data will indicate. Apparently, the application of lime was so small and the sewage so weak that the largely increased sewage flow of recent years has not been greatly benefited by lime treatment. The most objectionable features at Glenville are the odors arising from the sludge. When the humidity is high and the air is sultry, odors are said to be carried for considerable distance. Objectionable odors from sludge were noted on all visits to this plant. Conditions in this regard have always been more pronounced in the summer months and in 1907 the nuisance became so objectionable that from informal advice given during this investigation, it was decided to discontinue the use of lime. The present tanks were then operated as septic tanks and the sludge was allowed to accumulate. It was estimated that on the basis of the analysis of July 9th, 1907, the deposit would be only about 0.09 ton dry suspended matter per day, and that sufficient storage capacity was available for some time. On July 15th, 1907, the use of lime was discontinued, as already stated. Up to the time the plant went out of service entirely, the septic tanks were cleaned on one occasion only, some two weeks after they were first so operated, and then through the misjudgment of the operator. On the septic tank basis, there was some odor from the scum floating on the surface of the sewage in the first tank and this odor was noticeable perhaps 100 feet distant. After discontinuing the use of lime save for the one occasion when the septic tanks were cleaned by mistake, the sludge disposal nuisance at Glenville gradually decreased.

Coke Strainers.

The operation of the coke strainers in recent years has resulted in serious clogging, which, however, was prevented to a large extent by the cleaning and reconstruction of the strainers in 1906. The shallow settling basins appeared to be very efficient in retaining suspended matter.

From analyses made on July 9th, 1907, it was learned that the removal of suspended matter effected by the strainers was 24 per cent. and of organic matter, as indicated by the oxygen consumed, 33 per cent. There is, of course, no nitrification of organic matter.

Sand Filters.

The operation of the sand filters beginning in 1906 was virtually an experiment. Throughout this investigation, the filters have been out of service for long periods on account of clogging and the results obtained have strongly in-

dicated that the high rates of filtration attempted are not possible for fine grained material with sanded trenches specifically in cases where the applied sewage contains such a large quantity of organic matter and is so little purified as is the coke strainer effluent at this plant. Under ordinary operating conditions the sand filters soon become coated with a slimy covering of sludge and algae, and when drained they presented a very poor appearance. Shortly after cleaning, the filters were able to pass the applied sewage without ponding and as found on July 9th, 1907, produced a non-putrescible effluent. The effluent contained only a small quantity of nitrates and dissolved oxygen, but the organic matter had been somewhat oxidized and the effluent was ultimately stable.

SUMMARY.

On October 15th, 1907, the construction of the large intercepting sewer of the city of Cleveland had progressed sufficiently to permit of the disposal of the sewage of Glenville by this means. The increasing flow of sewage and the nuisance arising from the disposal of sludge from the chemical precipitation tanks had long since made necessary some radical step to improve the efficiency of the disposal of the Glenville sewage as effected by the old plant. Aside from odors from sludge, the coke strainers and sand filters repeatedly clogged and at times it was necessary to discharge large quantities of crude sewage without treatment. While the coke strainers have been in fairly successful operation during the year 1907, the sand filters even when provided with sanded trenches well underdrained and containing an excellent grade of lake sand failed entirely to produce a satisfactory effluent except for a short period immediately following the removal of the clogged surface sand. Furthermore, the operation of both the coke strainers and the sand filters has been possible only by constant care and with high costs of operation as will be next discussed. The abandonment of the plant practically solves a sewage disposal problem with which the plant in use during the greater part of this investigation could not cope successfully.

COSTS.

The first cost of the plant exclusive of land was about $20,500 partially itemized as follows:

Pumping station and machinery	$6,000
Settling tanks and sludge well	4,500
Sand filters	4,000

The cost of operation has gradually increased and especially in 1906, the operation of the plant required somewhat heavy expenditures on account of renewals and reconstruction. The plant is operated by two men whose combined salaries for 1906 and 1907, respectively, were $1,620. This is an increase of $300 over the salaries of 1903, which were $1,320. The total costs for the year 1903 were $2,300; in 1906, 3,858.35, and in 1907, 2,401.70. These costs on a per capita basis (Pop. 1903, 4,250; 1906-07, 6,500) are for 1903, 54 cents, and for 1906 and 1907, 59 cents and 37 cents, respectively.

The difficulties attending the operation of the plant in recent years greatly effected the cost of operation in 1906. In this year, of the total costs, the renewal of portions of the sand filters and the coke strainers cost $1,109.34; labor for cleaning and repairing the sand filters and coke strainers, $291.67; and for cutting grass and removing shrubbery, $27. In 1907, the cleaning of the coke and sand filters, respectively, required extra labor at a cost of $134.70.

During 1906 and 1907 about 500 pounds of lime have been used daily at a cost of $7.15 per ton, or at a daily cost of about $1.80. The coal consumption has been about 0.5 ton per day at a cost of about $1.15, so that including salaries the daily operating cost, exclusive of extra labor during 1906 and 1907, has been about $7.45, or about $6.20 per million gallons of sewage treated. Of this amount, $1.04 per million gallons is chargeable to the application of lime.

The following table shows operating costs for the years 1903, 1906 and 1907:

TABLE NO. 24.

Cost of Operation.

	1903	1906	1907
Salaries	$1,320	$1,620 00	$1,620 00
Extra labor	80	318 67	134 70
Coal and lime	900	810 34	*647 00
Sand and gravel	.....	1,109 34	.....
	$2,300	$3,858 35	$2,401 70

*About ten months.

The cost of sludge disposal cannot be separated from the general item of operation.

TABLE NO. 25.

Result of Chemical Analyses.

Date 1907.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.													
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.
					Organic.		Free Ammonia.	Nitrites.	Nitrates.							
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.				
Crude Sewage.																
July 9th.....	7:00 A.-10:30 P.	64	31	7	8.0	6.4	9.0	0.04	0.0	36	80	68	39	2.3	.....	87
July 9th.....	10:50 P.*	61	18	16	3.0	1.8	7.2	0.01	0.0	25	44	25	29	.....	.....	42
Weighted Av'ge.	.....	63	27	13	6.3	4.9	8.4	0.03	0.0	32	68	54	36	1.5	.....	72
Effluent Chemical Precipitation Tanks.																
July 9th.....	7:00 A.-10:30 P.	66	27	4.0	7.2	3.2	8.8	0.00	0.0	.....	50	35	.....	2.6	.....	61
Effluent Coke Strainers.																
July 9th.....	7:00 A.-10:30 P.	69	18	.....	7.0	.....	8.2	0.00	0.0	.....	38	25	.....	1.4	.....	.....
Effluent Sand Filters.																
July 9th.....	7:00 A.-10:30 P.	73	7.0	.....	3.0	.....	5.0	0.04	1.0	.....	43	20	.....	2.0	0	.....

* Representative night sewage.

OBERLIN.*

The village of Oberlin is a college town, the seat of Oberlin College, in Lorain County, in the north-central part of the state. Plum Creek, a small intermittent stream tributary to Black River, passes through the village. Public improvements have been increasing in late years and the town has a public water supply and water softening and purification plants, a system of sanitary and storm sewers and a sewage purification plant. A considerable part of the principal streets have been paved and there are now 4.8 miles of brick pavement. The water supply obtained from the east branch of the Vermillion River was placed in service in 1887 and the daily water consumption is now about 208,000 gallons. At the present time (1907) the village has a population of 5,200 in the winter, inclusive of 900 students; the summer population is only about 4,300.

SEWERAGE.

With the general use of the public water supply, a complete sewerage system became necessary and to the end of 1906 there had been built 2.0 miles of trunk sewers which comprise 1 360 feet of 8-inch pipe, 790 feet of 10-inch pipe and 8,650 feet of 18-inch pipe. The system contains eight manholes. Its cost, including engineering and land, was $10,500. It was extended during 1907 by the construction of 2,500 feet of 18-inch pipe which leads to a proposed new sewer farm. The cost of this extension was $3,000. The length of the trunk sewer at the end of 1907 was 2.5 miles.

In addition to the trunk sewers, the district sewers comprise 39,879 feet of 6-inch pipe and 6,721 feet of 8-inch pipe, 32 flush tanks and 29 manholes. There are further, cellar drains which comprise 34,654 feet of 4-inch pipe, 8,821 feet of 6-inch pipe, 3,537 feet of 8-inch pipe, 1,255 feet of 12-inch pipe. These sewers were laid with an average cut of 8.2 feet. The cost of cellar drain construction was about $3,000 per mile. The storm water and cellar drains discharge directly into Plum Creek. At the present time there are about 883 connections to the sewer system and it is estimated that the sewers are used by about 3,400 persons. There are practically no industries in the village which in any way effect the volume or the quality of the sewage.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

When about the year 1892, plans were discussed for a system of sanitary sewers for the village, the question arose as to what should be the ultimate disposal of the sewage, as there was no stream of water of sufficient size near Oberlin. Plum Creek was practically the only available outlet, and this stream, dry during the summer months, would unquestionably be so grossly polluted by the discharge of the crude Oberlin sewage that its use for this purpose would immediately be estopped by injunction suits. It was further recognized that a branch of the Black River, into which the sewage of Oberlin would eventually flow, at a point about 20 miles below the mouth of Plum Creek, was at that time used as a source of water supply for the city of Elyria. In view of these conditions, plans for the purification of the sewage of Oberlin were prepared when the sewer system was designed and they were approved by the State Board of Health to which Board the plans were referred in 1894. One of the prevailing methods of treatment in the early nineties will be recalled as broad irrigation, or sewage farming, and as such appeared to be the most readily adapted to Oberlin conditions, a plant along these lines was constructed. This plant has been in use since the year 1894.

* See Report on Water Softening at Oberlin, pp. 329-366.

Recently (1907), the sewer outlet was extended some 2,500 feet, plans for which were referred to the State Board of Health and were approved on condition that there be constructed a new and enlarged sewage plant on more modern lines whereby a satisfactory purification of the Oberlin sewage would be insured at all times. The necessity for a new sewage plant was made strongly evident in the summer of 1906, when complaint of a nuisance from odors was made by a farmer living in the neighborhood of the plant, who threatened to bring suit for damages against the village, but agreed to leave the matter in abeyance provided the village would change the location of the sewage farm to a point about one-half a mile east of its present location and about the same distance removed from his residence. A strip of land comprising several acres was forthwith acquired by the village and the construction of the extension of the sewer outlet was begun and completed in 1907. Local politics have caused more or less delay in the construction of the new plant, plans for which were submitted to the Board and have received a partial approval. It is probable that the work will be begun in 1908. In the meantime the old plant is being operated with fairly satisfactory results, especially in view of the fact that its capacity has long since been exceeded, and further in view of certain other features, chiefly of operation, which will be fully discussed subsequently.

EXAMINATIONS AND INSPECTIONS.

Visits of inspection were made in 1906 on April 14, and in 1907 on Jan. 18, Mar. 21, Aug. 21 and Oct. 23. On Aug. 24, 1906, there was made a partial examination of the plant.

DESCRIPTION OF PLANT.

The sewage plant of the village of Oberlin is on a 20-acre tract of land about 1½ miles east of the built-up portion and on the south side of the Elyria pike. Of the twenty acres purchased, only six bordering on the creek and at a considerable distance from the pike are at an elevation low enough to receive the village sewage by gravity. This area, which was prepared for broad irrigation, receives sewage which has received chemical treatment and rough sedimentation in small settling tanks or sludge pits as they are locally called.

DEVICES FOR APPLYING CHEMICALS.

Since April, 1904, lime and copperas have been applied to the crude sewage.

Copperas Dissolving Tank. Copperas is applied from a small wooden tank 4 feet in diameter and 3 feet 8 inches deep, with a capacity of about 350 gallons. The tank is located in the chemical house of the water softening plant. One of the laterals of the sewer system ends at this point and into it the solution of copperas is discharged. Water for dissolving the chemicals is supplied through a faucet. The solution of copperas flows from the tank through a 2-inch opening in the bottom.

Lime Solution Tank. This is a wooden tank 3 feet 6 inches in diameter and 7 feet deep with a capacity of about 500 gallons. The tank is located over the trunk sewer at a point below the entrance of the greater part of the laterals. To dissolve the lime, a pipe is introduced from which flows a jet of water under city pressure. The milk of lime overflows through a 6-inch vitrified sewer pipe directly into a manhole on the trunk sewer. There is a 2-inch opening in the bottom of the tank controlled by a wooden plug, which is opened when charging.

Sludge Pits.

The unscreened sewage flows from the main sewer into the sludge pits. These are two in number and are uncovered rough excavations in the natural soil. The sides of the pits are boarded up and braced. Each pit is about 10x30 feet in plan and 3 feet deep and has a capacity of about 6,700 gallons.

Inlets and Outlets. The main 18-inch sewer discharges into a pit with its invert about 9 inches below the flow line of the tank. There are two outlets in each tank and these consist of channels cut in the soil through which the sewage flows to and over wooden weirs.

Baffles. In 1906, three baffles were provided in each tank; the first is 5 feet from the inlet. The baffles are 10 feet apart and are constructed of 12-inch plank. The first and third baffles extend 2 feet 9 inches below the flow line, but the second baffle is submerged and extends from the bottom to within about 3 inches of the surface of the sewage.

Filters.

Of the entire area of approximately six acres, 3.5 acres are prepared for operation as intermittent sand filters. An additional area of 1¾ acres, not underdrained, is arranged for broad irrigation. The area for intermittent filtration is divided into 12 units by 1-foot earth embankments.

Filtering Material and Underdrains. The filters are constructed from the natural material in place, by underdraining with lines of 4-inch agricultural tile laid 20 feet apart and at a depth of 3 feet. The bottom of the trenches is clay puddle and over the underdrains similar material is placed to a depth of 2 feet to prevent the passage of unpurified sewage. The lower tier of filters adjacent to the river is composed of fine river loam with an effective size of 0.09 m.m. and a uniformity coefficient of 2.8. The upper set of filters contains yellow clay with an effective size of 0.09 m.m. and a uniformity coefficient of 4.2.

Dosing, Distributing and Discharging Apparatus. The sewage is applied to the plant directly from the sludge pits or settling basins through ditches cut in the natural soil. The diversion of the sewage to the different units or to the irrigation area is effected by closing the ditches with earth. The effluent flows from the filters by gravity through short lengths of 4-inch tile which lead to the creek. In recent years when, as will be brought out later, the filters have been operated as settling basins, sewage has been allowed to spill over the sides of the low embankments. As the irrigation area is not underdrained, considerable clarified sewage is discharged into the creek merely after passing over the area used for irrigation. The plant is generally inundated during extremely high water and in such cases no treatment of the sewage is attempted.

SEWAGE FLOW.

One series of half-hourly measurements lasting 24 hours was made during this investigation on Aug. 24, 1906. The sewage flow ranged from a rate in 24 hours of from 200,000 gallons in the daytime to 20,000 gallons at night. According to the reports of the city engineer, the sewage flow has largely increased in recent years. In the year 1901, the flow was about 100,000 gallons and in two years had increased to an average of about 250,000 gallons in dry weather, as has been the average flow during this investigation. This average flow is about 74 gallons per person tributary. Correspondingly, the water consumption per consumer in 1907 was 57 gallons, and in view of this it is evident that there is considerable leakage into the sanitary sewers. During storms, moreover, the sewage flow is very largely increased.

COMPOSITION OF CRUDE SEWAGE.

No analyses of the raw sewage are available, in view of the fact that during this investigation chemicals have been applied to the sewage at two points in the village as already stated. There are no manufacturing wastes discharged into the sewers and the sewage is essentially domestic, and in view of the softening of the public water supply of the village is probably unusually soft for Ohio conditions. It is interesting to note that the phenol alkalinity of the Oberlin water disappears when the water becomes sewage.

OPERATION.

The sewage purification plant, or sewage farm as it is locally called, is under the general direction of the sewer committee of the city council and under the direct charge of the city engineer. An employee of the village is placed in charge of the application of the chemicals and visits the plant several times each week to change the gates and to attend to other matters relative to its operation. At times extra labor is employed in cleaning and plowing the filters.

Application of Chemicals.

According to the village records, chemicals were first applied to the Oberlin sewage in the years 1901 to 1903 when alum was used. Copperas and lime were first applied in April, 1904. Until the winter of 1906 and 1907 no chemicals were applied from December to March. As advised by the State Board of Health, from the results of this special investigation, since the winter of 1906 and 1907, lime and copperas have been applied throughout the year, except under heavy storm flows or when Plum Creek has been in flood.

Copperas. In 1906, there were daily applied 210 pounds of copperas in three doses of 80, 70 and 60 pounds, respectively, which were applied at 7:00 and 11:00 o'clock A. M. and 4:00 o'clock P. M. The dry chemical is placed into the dissolving tank, already described, into which a small stream of water is caused to flow. The solution of copperas thus formed, flows thence to a manhole on one of the lateral sewers. The copperas is applied at the water softening plant at a point about one mile above that at which the lime is added. On the visit of Jan. 28, 1907, it was found that the quantity of copperas used daily was 220 pounds. This weight of copperas corresponds roughly to six grains per gallon. In the fall of 1907, it was found that the quantity of copperas used daily was 300 pounds. This corresponds to about 8.4 grains per gallon. The application is, of course, very irregular and at times one dose of copperas has not been completely dissolved before the next dose is added.

Lime. In the summer of 1906, when the application of chemicals was resumed, lime was applied in three daily doses at the same hour as the copperas, in quantities of 90, 90 and 50 pounds, respectively, or a total daily quantity of 230 pounds. The lime used was the ordinary commercial quicklime. In applying the lime, the proper quantity of the slaked or of the hydrated chemical is placed into the lime barrel already described. On to this lime flows the jet of water which causes the formation of a fairly thick milk which overflows from the barrel into the sewer. Before charging the lime barrel, it is customary to wash out the lime deposit on the bottom by opening the wooden plug. At such times, therefore, unusually large doses of lime are applied. There is no regulation whatever and no means are provided for mechanical agitation. It is obvious that this method of applying lime is very crude and that towards the end of a run the actual quantity of available lime is very slight. Some difficulty is always experienced in cold weather on account of the freezing of this apparatus, and when winter treatment

with chemicals was begun, the lime tank was housed. The application of lime in the quantity above stated, corresponds roughly to the use of 6.4 grains per gallon. It is intended that the quantity of lime applied shall be sufficient to neutralize the free and half-bound carbonic acid in the soft water sewage of the village and to allow a slight phenol-alkalinity. About three hours are required for the lime-treated sewage to reach the sewage purification plant. At times the coagulation effected is excellent, especially when a fresh charge of lime is applied, but at other times the coagulation entirely disappears. In the winter of 1907, about 210 pounds of lime were used and this practice was continued until September, 1907, when hydrated lime was substituted for the ordinary commercial quicklime. Of this hydrated product, 400 pounds are said to have been used daily, an actual increase of 90 pounds expressed in terms of ordinary quicklime. This procedure, said to be followed at the present time, corresponds to the use of about 8.4 grains of commercial lime per gallon.

Sludge Pits.

Comparatively little attention is required in the operation of the sludge pits. Prior to the year 1906, these tanks were not baffled and considerable labor was involved in cleaning the filters and the irrigation area on account of the large quantities of septic sludge, which from time to time were carried out of the tanks with the effluent. The tanks were subsequently baffled, as already stated, and were then operated as septic tanks. One tank alone is ordinarily in service and based upon the average sewage flow, the period of flow of the tank is only, roughly, 40 minutes. corresponding to a linear velocity of about 3.75 m.m. per sec. In the early history of the plant, sludge from time to time was removed by pumping on to adjacent land and when slightly dried was spaded in. An inspection of this sludge indicated that it rapidly oxidized and was probably septicized to such an extent that no obnoxious conditions were created by its discharge. It is stated that the sludge was removed by a diaphram pump of 4-inch suction which discharges into a tank wagon. After the tanks were baffled it was considered better practice to allow the sludge to remain, with a view that the suspended matters forced from the tank could readily be arrested on to the filters and irrigation area before reaching the creek. It has been the practice, however, from time to time to remove sludge from these tanks. The operation of the pits, has shown that the heavier matters are deposited in the first compartment and that the second and third contain principally finely divided sludge. On all visits, it was noted that copious volumes of gas were being formed in the sludge deposit.

Filters and Irrigation Area.

About the year 1903, nine years after the plant was first placed in service, it was recognized that its capacity was exceeded, as it was found that the clayey area rapidly clogged and eventually became impervious, even though well underdrained. After this date, as now prevailing, the filters were operated practically as subsidiary settling basins for the septic effluent. Ordinarily, sewage is allowed to flow on to one of the basins or filters until the water begins to flow over the sides of the dividing embankments. Under such conditions. of course, the volume of sewage is greater than the quantity of water which can be carried away by the tile underdrains. As soon as the basin is filled. the flow is diverted to another area and the sewage in the basin just in service is allowed to stand for a period of 24 hours. A channel is then cut in the embankment and the supernatant liquid is allowed to flow directly into the creek. The filters are cleaned from time to time and it has been the general practice to allow the material to dry, for in this condition it cracks and curls and may be more readily removed. Since the con-

struction of the new sewage plant was delayed, with a view to improving operating conditions as much as possible, the filters were plowed and harrowed in the summer of 1907. At times, the sewage is diverted to the irrigation area by means of the earth ditches and it flows in thin streams over the grass and generally the greater part seeps into the subsoil.

Based upon the total area of filters and irrigation area, the average rate per acre in 24 hours is about 48,000 gallons or in terms of the tributary population, about 650 persons per acre.

EFFICIENCY.

Due to the inferior character of the soil, and the increased volume of sewage, the plant for some years has been overtaxed, as before stated, and as a result the filters have been operated as ponds or settling basins with the thought of avoiding the construction of a new plant or of enlarging the former plant. The filtration area has received the chemically precipitated sewage prior to the year 1907, but eight months of the year only. From December, 1905, to June, 1906, no chemicals were applied to the Oberlin sewage, although spring treatment is usually commenced in March. The absence of chemical treatment caused foul odors to emanate from the creek and led to agitation which resulted in the extension of the sewer outlet and started the movement for the construction of a new and enlarged sewage plant.

Ordinarily, the plant has accomplished only a rough clarification of the sewage and has not rendered it non-putrescible. This condition, of course, is attributable to the very irregular application of the chemicals, to the feature of rapid clogging, and to the poor quality of the natural soil of which the filters are constructed. Moreover, for the past five years there has been no purification, except that incidental to the passage of the chemically precipitated sewage over the irrigation area, as the filters have merely served to arrest some of the suspended matters in the applied septic sewage. On the detailed examination of Aug. 24, 1906, partial analyses were made of samples of the applied sewage and the effluents from the settling basins and from the filters, respectively. The samples were collected at half-hourly intervals for a period of 12 hours and were mixed in equal proportions. It appears from these analyses that the treated sewage as discharged from the plant contained considerable organic matter and moreover, with the exception of that representative of the small volume of effluent which flowed from the underdrains, the samples were distinctly putrescible and on incubation developed a most offensive odor. At times, however, it appears possible to obtain satisfactory results by chemical treatment, rough sedimentation and irrigation, as practiced at this plant. On the visit of Aug. 21, 1907, a remarkable purification was being effected by the plant. The past summer has been one of considerable drought and Plum Creek was at this visit merely a succession of shallow pools. Below the plant, therefore, the waters in the creek were practically entirely treated sewage. The liquid was apparently non-putrescible. Slight sludge deposits were noted on the bottom of the stream, but in general the disposal of the sewage of Oberlin was at this time being effected without nuisance. The creek was examined for a distance of one-half mile below the farm; no odors were noted and practically no deposits of sludge were observed.

SUMMARY.

The results obtained from the present old sewage farm at Oberlin, while at times satisfactory, at other times are very poor, due particularly to the fact that the capacity of the plant has long since been exceeded and in part to the irregular application of chemicals which are largely depended upon to remove the organic

impurities from the raw sewage. It appears that the passage of the chemically treated sewage in thin streams over grass land, especially in view of the iron contained in the soil and derived from the copperas applied, has considerable beneficial effect in the oxidation of the organic matter. Winter treatment is now regularly carried out and the importance of an all-the-year treatment is strongly emphasized from Oberlin experiences, in view of the fact that complaints from odors, which are noticeable in the warmer months of the year, may be traced to deposits of sludge in the colder months when the sewage is discharged without treatment. The exceeded capacity of the plant and the nuisance created in the spring of 1906, brought about the extension of the sewer outlet and caused a movement for a new sewer farm of greater capacity. The construction of the new plant, owing to local politics, has temporarily been held up at the present time. Evidence available from this investigation indicates strongly that the construction of a new plant is urgently necessary, since the capacity of the old plant has long since been exceeded, and since the purification afforded, while perhaps satisfactory at times, is generally such as to cause a decided pollution of Plum Creek.

COSTS.

The first cost of the present sewer farm was $2,490, divided as follows:

Land	$1,500
Preparation	990
	$2,490

The operating expenses are confined chiefly to the cost of chemicals, although occasional small expenses are incurred for labor. In late years, the cost of operation has been slightly less than $500. but in the year 1907 it was $700, an increase due to the fact that the sewage was treated with chemicals throughout the year. The annual operating expenses for the years 1902 to 1907, inclusive, are shown in the following table, together with the estimated population tributary to the plant, and the annual costs per person tributary.

TABLE NO. 26.

Annual Costs of Operation for the Years 1902 to 1907, Inclusive.

Year.	Cost of Operation.		Persons Tributary.
	Total.	Cents per Person Tributary.	
1902	$432 00	15	2,800
1903	250 00	9	2,800
1904	285 00	9.5	3,000
1905	431 40	13	3,200
1906	474 16	15	3,200
1907	700 00	21	3,400

TABLE NO. 27.

Results of Chemical Analyses.

Date 1906.	Hour of Collection.	Parts Per Million.					
		Oxygen Consumed.		Nitrogen As			Putrescibility.
				Organic.		Free Ammonia.	
		Total.	Dissolved.	Total.	Dissolved.		
		Outlet Septic Tanks.					
August 24	8:30 A.-8:00 P.	25	.....	4.8	.....	21.0	+
		Supernatant Sewage on Filters or Settling Basins.					
August 24	8:30 A.-8:00 P.	16	.....	6.3	.....	17.5	+
		Outlet Tile Drains.					
August 24	8:30 A.-8:00 P.	24	.....	3.3	.....	22.5	+

ASHLAND.

The village of Ashland, the county seat of Ashland County, is near the headwaters of Jerome Fork, a minor tributary of the Muskingum River, and according to census reports has an estimated population of 7,500. There are large manufacturing interests in Ashland, and these embrace the manufacture of machinery, stock food, rubber goods, bed springs and door hangers. The village is surrounded by rich farm land and its railroad facilities are such as to afford ample opportunities for the shipment of farm products. A number of municipal improvements have been carried out and dating from about the year 1895, the village has had a public water supply consisting of a system of driven wells, from which the daily consumption is about 336,000 gallons. Other improvements include the paving of the principal streets. and the construction of sanitary and storm sewers. To the end of 1907, there have been built 7.1 miles of brick pavement.

SEWERAGE.

The sewerage of the village consists of a system of sewers for domestic purposes which were designed to conduct the sewage by gravity to a sewage purification plant a short distance east of the corporation line. Some storm sewers have also been built to supplement the drainage afforded by natural watercourses. The sanitary sewers were installed in 1902, and now (1907) comprise 13.9 miles of vitrified pipe sewers, which range in size from 6 to 15 inches. There are 13.5 miles of sanitary sewers within the village and a trunk sewer 0.4 mile in length extending from the corporation line to the sewage purification plant. The records

Ashland. — Septic Tanks Before Covered, Showing Heavy Scum at Inlets.

of the sewer department show that at the end of 1907, there were 556 house connections to the sanitary sewers. The total population tributary to the sewers is estimated at 3,000 persons. Practically no manufacturing wastes are discharged into the sewers, but for sanitary purposes some 40 factories and public buildings are connected and these serve a population estimated at about 1,730. Connections other than residential are listed as follows:

Kind.	Number.	Persons Served.
School Houses	4	755
College	1	150
Manufacturing Establishments	5	828
Business Blocks	31	.....
Churches	4	.....
Laundries	2	.....

While the Ashland sewers are on the separate system, the sanitary sewers receive considerable ground water and roof water, although recent inspection by the village officials has materially reduced the number of down spouts connected to the sanitary sewers. As true at a number of places where sewers are ostensibly on the separate plan, during storms and long continued wet weather, the sewage flow is greatly increased by ground water and roof water and the sewage itself is highly diluted.

In addition to the strictly sanitary sewers, there are about 3.1 miles of brick and pipe storm sewers. The brick sewers are 36 inches in diameter and have a total length of 4,400 feet. The pipe sewers range from 10 to 24 inches in size and have a total length of 12,000 feet or 2.3 miles.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In March, 1899, a resolution was adopted by the village council of Ashland requesting the Board to send a committee to investigate and report upon the sanitary condition and needs of the village. A committee was subsequently appointed and it reported that there was an urgent need for a sewerage system, as the sanitary condition of the town was very poor. It was made clear to the Ashland authorities that any system of sewers must provide for purification. Suggestions were also made that there be appointed by the mayor of Ashland five sewer commissioners to have charge of the construction of the sewer system and to employ a competent engineer. Shortly afterwards the system of sanitary sewers as now in use was placed under construction and was completed in 1902. The purification of the sewage as advised by the Board's special committee was distinctly necessary with a view to preventing nuisances on account of the small dilution afforded by Jerome Fork, which has a dry weather flow of perhaps from 2 to 3 cubic feet per second, and would be sufficient satisfactorily to dilute the sewage of less than 1,000 persons. Full plans for the sewers and for the sewage purification plant were submitted to the Board and were approved in August, 1901. The plant first placed in operation in 1902, in general terms comprises grit chambers, septic tanks, and intermittent filters composed of sandy gravel. Fortunately, the topography of the village allowed the sanitary outfall sewer to be placed at an elevation sufficient to conduct the sewage to the purification plant by gravity.

EXAMINATIONS AND INSPECTIONS.

During this special investigation, the Ashland plant was examined in detail in 1906, on July 11-12 and Nov. 16, and in 1907, on April 24-25. It was inspected on April 25, 1906, Feb. 15, 1907 and July 16, 1907.

DESCRIPTION OF PLANT.

The Ashland sewage plant is located on a 20-acre tract of bottom land about 0.4 mile outside the corporation line east of the village near Jerome Fork, and 1.5 miles from the center of the village; the nearest house is one-fourth mile distant.

Grit Chambers.

The crude sewage arriving at the plant through the 15-inch trunk sewer is not screened but discharges directly into the grit chambers. (See Plate XXV.) These are three in number, 4 feet wide, 10 feet long and 4 feet 2 inches deep and each of about 1,260 gallons capacity. The operation of the grit chambers is controlled by 8-inch gate valves on the inlets. Sewage flows from each grit chamber directly through an 8-inch elbow which pierces the brick wall which separates the grit chambers and the septic tanks. A 4-inch line controlled by a 4-inch valve permits the discharge of sewage from the grit chambers to a sludge disposal area.

Septic Tanks.

The septic tanks are three in number and are each 28 feet long, 10 feet 4 inches wide and 6 feet average depth. The depth to the flow line ranges from 5 feet 6 inches to 6 feet 6 inches. The average capacity of each tank is 13,000 gallons. The tanks are constructed of brick and are cement plastered. The walls are 2 feet thick and the bottom 6 inches thick. The tanks were originally without a roof, but recently (1907) they have been provided with a covering composed of 2-inch plank, which comprises 12-foot lengths cleated together and closely fitted to valves. There is no available head room for purposes of inspection and there are no manholes. (See Plate XXVI.)

Inlets and Outlets. The sewage enters each tank through an 8-inch elbow turned downward to a point 18 inches below the flow line and on the longitudinal center line of the tank. The sewage flows from each tank in a thin sheet over the end wall, which is slightly depressed below the side walls, into a cement-lined trough of semi-circular cross section, extending the full width of the three tanks.

Baffles. A scum baffle is provided 2 feet from the outlet end and extends across each tank. It is constructed of 3/16-inch wrought iron, and is 10 feetx2 feet 6 inches in plan and is submerged to a depth of 2 feet.

Sludge Drain. The floor of the tanks slopes 1 in 30 from inlet to outlet, at which point a sludge drain is provided. It consists of a 6-inch pipe which is increased for the main line to 8 inches. The flow from the 6-inch drain is controlled by a 6-inch gate valve.

Method of Control. The septic tanks are controlled only by the 8-inch gate valves at the entrance to the grit chambers; sewage flows from the tanks by gravity.

By-pass. The 15-inch main sewer at the plant terminates in a 3-foot manhole adjacent to the grit chambers. This manhole contains a 12-inch gate valve, which allows the entire sewage flow to be by-passed to the creek.

Measuring Weirs. No facilities were provided in the construction of the tanks for measuring the sewage flow, but in the earth channel through which flows

the septic effluent, for the purposes of this investigation there was built a weir, by means of which there have been obtained daily measurements of the sewage flow.

Sludge Disposal Area.

For the purpose of disposing of the sludge from the septic tanks, a portion of one of the intermittent filters is set apart by means of an earth embankment. This sludge filter is 0.15 acre in area and is underdrained with lateral drains of 3-inch tile, 25 feet apart. These lead to main collecting drains of 8 and 10-inch vitrified sewer pipe, respectively. Sludge from the septic tanks may be discharged on to this filter by gravity.

Filters.

The intermittent filters at Ashland comprise six units of sandy gravel, which range in size from 0.54 to 1.04 acres. The total area is 4.99 acres. These filters were prepared by underdraining the natural soil found on the site selected for the plant. The six filters are separated by earth embankments which are covered with a rank growth of vegetation. (See Plate XXV.)

Filtering Material. The filtering material is a sandy gravel with an effective size of 0.24 m.m. and a uniformity coefficient of 2.2. The depth of the filtering material over the underdrains ranges in the several filters from 23 to 30 inches and averages 26 inches.

Underdrains. The underdrainage system comprises lateral lines of 3-inch tile, which lead to the main collectors from 8 to 12 inches in size. The lateral drains are the ordinary soft porous tile and are laid 25 feet apart. No lantern holes nor other special means of ventilation are provided. In four of the filters no coarse material is placed over the lateral tile drains, and in these cases trenches are merely made in the natural soil in which is placed the underdrain tile. In 1906, as a result of a detailed examination of the plant, it was advised that the entire original area should be placed in service. This advice necessitated the reconstruction of two of the filters which had not been in use for some time owing to the clogged condition of the underdrains. Accordingly, extensive reconstruction was carried out and in the case of two of the filters the underdrains were removed and replaced and the trenches over the drains 18 inches in width were filled to the surface of the filters with a gravelly sand, which, exclusive of about 28 per cent. of large stones, has an effective size of 0.20 m.m. and a uniformity coefficient of 23.0.

Dosing Devices. No special apparatus is in use for dosing the filters which are supplied with effluent from the septic tanks through channels cut in the earth embankments which separate the several units. As suggested during visits to the plant made in 1906, for the purpose of diverting the sewage from one filter to the next, there are in use wooden sluice gates 18 inches wide and 12 inches deep. Each is provided with a wooden shear gate which when closed is readily made tight with a small quantity of earth.

Distribution Devices. Carried by the earth ditches, just described, the sewage flows on to a pile of stones in one corner of each filter. No provisions are made for a more thorough distribution of the sewage on the filters proper.

Effluent Discharge. The effluent from the filters collected in the 8 and 12-inch vitrified drains is discharged by gravity through one length of 10-inch iron pipe. No special provisions are made to protect the plant from high water, except the earth embankments formed by the removal of the original top soil from the six filters. Occasionally during heavy storms, the relative elevation of the filters and the creek is such that the plant is flooded, but during high water in the creek no attempt is made to purify the sewage of the village.

SEWAGE FLOW.

From measurements made during the special investigation of the Ashland plant, and from the daily records of weir heights as kept by the superintendent, the quantity of sewage at Ashland at the present time (1907) averages 340,000 gallons in 24 hours, or 113 gallons per person tributary. In the dryer months it falls to a rate of from 220,000 to 240,000 gallons in 24 hours. On July 11-12, 1906, the night flow from 10:30 o'clock P. M. to 6:00 o'clock A. M. was at the rate of 123,000 gallons in dry weather. This high night flow, of course, indicates considerable infiltration of ground water and probably some leakage from water fixtures. The water consumption, as already stated, averages about 336,000 gallons daily and in view of the sewage flow during the dryer months, quite a large part of the water used does not reach the sanitary sewers. During storms and wet weather the flow of sewage is greatly augmented and may reach 1,000,000 gallons in 24 hours. Sewage flow data available from the daily records kept at the Ashland plant are listed in Table No. 28 which shows the range of sewage flow by months for a considerable part of the period covered by this investigation.

TABLE NO. 28.

*Sewage Flow by Months.**

Month.	Sewage Flow, Gallons in 24 Hrs.			Rainfall (Inches).
	Average.	Maximum.	Minimum.	
June, 1906	187,000	272,000	153,000	3.5
July	200,000	304,000	177,000	3.4
August	144,000	492,000	92,000	2.51
September	160,000	492,000	92,000	3.98
October	248,000	570,000	92,000	2.65
November	335,000	1,030,000	207,000	2.15
December	488,000	1,090,000	306,000	2.82
January, 1907	738,000	1,090,000	343,000	4.62
February	405,000	545,000	306,000	.....
March	498,000	562,000	470,000	.....
April	451,000	728,000	252,000	2.28
May	588,000	726 000	409,000	4.48
June	423,000	658,000	303,000	6.21
July	316,000	657,000	160,000	3.34
August	231,000	529,000	122,000	1.62
September	220,000	330,000	139,000	0.65
October	240,000	470,000	139,000	2.03
November	200,000	529,000	154,000	1.55
December	340,000	1,130,000	148,000	2.03

* One daily weir measurement made at different hours each day from 7:00 A. M. to 5:00 o'clock P. M.

The following data illustrating the high night flow were obtained during the 24-hour examinations of July 11-12, 1906, and April 24-25, 1907, respectively. The increase in flow during the wet weather of spring is deserving of special comment.

TABLE NO. 29.

Hourly Variation in Sewage Flow and Percentages of Average for Different Hours of the Day and Night.

Hour.	Rate of Flow — Gals. in 24 Hrs.		Percentage of Average.		Hour.	Rate of Flow — Gals. in 24 Hrs.		Percentage of Average.	
	July 11-12, 1906.	April 24-25, 1907.	July 11-12, 1906.	April 24-25, 1907.		July 11-12, 1906.	April 24-25, 1907.	July 11-12, 1906.	April 24-25, 1907.
A. M.					P. M.				
6:00	136,000	440,000	91	117	6:00	207,000	382,000	139	102
7:00	153,000	440,000	103	117	7:00	176,000	409,000	118	108
8:00	189,000	440,000	127	117	8:00	153,000	409,000	103	108
9:00	189,000	440,000	127	117	9:00	153,000	356,000	103	94
10:00	326,000	409,000	152	108	10:00	136,000	356,000	91	94
11:00	226,000	440,000	152	117	11:00	136,000	356,000	91	94
12:00	226,000	409,000	152	108	12:00	120,000	330,000	81	88
P. M.					A. M.				
1:00	176,000	382,000	118	102	1:00	120,000	356,000	81	94
2:00	207,000	409,000	139	108	2:00	120,000	302,000	81	80
3:00	207,000	409,000	139	108	3:00	120,000	302,000	81	80
4:00	207,000	409,000	139	108	4:00	120,000	330,000	81	88
5:00	176,000	409,000	118	108	5:00	120,000	302,000	81	80

COMPOSITION OF CRUDE SEWAGE.

The crude sewage of Ashland may be considered as a typical domestic sewage generally, greatly diluted by ground water leakage and the somewhat free use of water by the inhabitants of the village. There are practically no manufacturing wastes discharged into the sewers. Average samples of the crude sewage for periods of 24, 12 and 24 hours, respectively, were collected at half-hourly intervals during the three detailed examinations of the plant and the individual portions were mixed to form a composite in proportion to the sewage flow. A majority of the analytical determinations were carried out in the field and in general the conduct of the examination of this plant conformed to the general methods of making such examinations as already set forth in detail.

The chief characteristics of the Ashland crude sewage are its high dilution and the general presence of small quantities of dissolved oxygen.

OPERATION.

The method of operating the Ashland sewage plant has been decidedly changed since this investigation was begun in 1906, and the general tendency has been toward the use of the filters on a strictly intermittent basis and toward the operation of the preparatory devices on a septic tank basis, that is, with an infrequent removal of sludge. The plant is in charge of the superintendent of sewers.

Preparatory Devices.

Under normal conditions of sewage flow, two grit chambers and two septic tanks are in service at one time and by adjusting the 8-inch inlet valves each is

caused to receive an equal quantity of sewage. With the average sewage flow (1907), the period of flow in the grit chambers and septic tanks, respectively, with two tanks in service, is about five minutes and one and one-half hours, respectively, and the respective linear velocities are 4.0 and 1.5 m.m. per second. In the latter part of 1907, all three tanks are in use with an approximately equal flow through each. It is the general practice to empty and clean the grit chambers at about bi-weekly intervals, as they accumulate large quantities of organic material. Occasionally also, in the past and at the present time, it is customary thoroughly to agitate the sewage in the grit chambers with a view to causing the heavy accumulations of organic matter to pass into the septic tanks. The septic tanks developed a heavy scum formation which gave rise to such a decided nuisance from odors that during the first examination of the plant in the spring of 1906, advice was given to remove and bury the scum. In the spring of 1907, odors from the scum on the tanks again became objectionable and it was finally decided to cover the tanks with a flat board cover. This was done in May, 1907. and resulted in minimizing odors from the septic tank, a result due in a large part it is thought to the fact that the roof prevents the disturbance of the scum by rain and wind and allows a more rapid oxidation of the surface of the scum which, when finally oxidized, of course, is without odor.

Sludge Disposal.

At the beginning of the investigation, it was found that it was the practice to discharge the contents of the grit chambers and septic tanks at bi-weekly intervals. This plan, of course, entailed very little extra labor and practically no added operating expenses, owing to the adjacent sludge area with gravity discharge of sludge as originally provided in the design of the plant. Such frequent discharge of sludge which, of course, on account of its short retention under septic conditions, was organic material practically in a crude state, caused such a decided nuisance from odors that during the first detailed examination of the plant, the official in charge was advised to discontinue the practice of removing sludge so frequently and to operate the tanks as septic tanks, allowing a storage of sludge until the effluent from the tanks should begin to contain abnormal amounts of suspended matters.

This recommendation was carried out at once and since the spring of 1906, sludge has been removed from the Ashland septic tanks on five occasions only, namely, July 12-14, 1906; Sept. 24, 1906; Oct. 24, 1906; June 17-20, 1907, and Dec. 2-3, 1907. In cleaning the tanks, only the lower semi-liquid portions have been removed through the sludge drains and in each instance the scum on the surface of the tanks has been allowed to remain. In June, 1907, however, before the tanks were covered, they were entirely cleaned and the scum itself was removed and buried.

The approximate quantity of scum and sludge in the septic tanks, as noted on the three detailed examinations of the plant, is listed in the following table. The rather small accumulation is probably to be explained by the general weakness of the crude sewage in part, but in greater part perhaps by virtue of scouring actions in the tanks during the increased sewage flows incidental to wet weather. On April 24. 1907, the scum on tank No. 3 was sufficiently tenacious to bear the weight of a man.

TABLE NO. 30.

Scum and Sludge Accumulation in Septic Tanks.

Date.	Scum.						Sludge.					
	Inches.			Cubic Yards.			Inches.			Cubic Yards.		
	Tank No. 3.	Tank No. 2.	Tank No. 1.	Tank No. 3.	Tank No. 2.	Tank No. 1.	Tank No. 3.	Tank No. 2.	Tank No. 1.	Tank No. 3.	Tank No. 2.	Tank No. 1.
July 18, 1906.	14–5	6–4	0	8.5	5.2	0	0	0	0	0	0	0
Dec. 8, 1906.	16–2	6*	9†	6.1	0.7	1.8	0	0	0	0	0	0
April 24, 1907	30–5	32–8	0	41	16	0	15–9	0	48–0	7.6	0	55

* 4 feet from inlet. † 9 feet from inlet.
Gradual decrease in thickness of scum and sludge inlet to outlet.

Filters.

Prior to the visits made in the spring of 1906, only five of the seven filters were in serviceable condition and these were operated continuously as in water filter practice with one unit in service for a period of one week or longer. The average rate of filtration is 68,000 gallons per acre in 24 hours, and the population load is only 600 per acre. During the first inspection of this plant, the attention of the village authorities was called to the desirability of using the filters in rotation so as to afford a period of rest. The officials were further advised to place in service the entire available area, both of which recommendations were carried out. Since the spring of 1906, therefore, the sand filters at Ashland have been operated strictly on an intermittent basis. One unit is in use each day and the filter receiving sewage is generally changed in the morning. The filters are plowed, harrowed and leveled about twice a year, but no filtering material is removed. At the request of the Board, for the purposes of this investigation, careful records have been kept of the operation of the plant, including daily weir readings, temperature observations and general information pertaining to the operation of the filters. As before stated, the filters are by-passed during storms, in case of repairs and when cleaning the septic tanks. From the daily records it appears that since April, 1906, the plant has been by-passed on 93 days, in 1907, as follows: Jan. 19-27, Mar. 11, April 8, April 23, May 6-7, 16-21, 24-29, June 12, July 3, July 14-17, Oct. 21-27, Nov. 2-3, Dec. 2-4, 23-24, and 30-31. The winter visit of February 15, 1907, showed that the plant was being operated as during the warmer months and that the filters when used in rotation could be operated during cold weather without serious ponding with its accompanying decreased efficiency.

EFFICIENCY.

Analytical evidence obtained during the three detailed examinations at Ashland, together with general observations made during the three inspections of this plant, show that since the filters have been used in rotation the efficiency of the

plant has been high and that the small stream into which the effluent flows has suffered but little measurable organic pollution thereby.

Preparatory Devices.

From the standpoint of efficiency in the removal of suspended matter, preparatory treatment at Ashland is of small moment. The low efficiency of the grit chambers and septic tanks brought out by analyses of samples collected during the three detailed examinations of the plant is, of course, in greater part to be attributed to the small combined capacity of these preparatory devices.

The grit chambers in common with those at a number of plants in the state, do not serve their intended purpose, but intercept chiefly suspended material of a highly putrescent character. The frequent necessity for emptying the grit chambers for cleaning, due to loss in capacity because of rapidly accumulating organic material and of agitating the contents of the tanks so that some of the deposits may be carried forward for hydrolysis in the septic tanks, shows clearly the strong advisability of omitting grit chambers from a plant, when the sewers of the city or village are on the separate plan.

In all of the detailed examinations of the Ashland plant, samples were collected from the effluent of the septic tanks. Based upon the weighted analyses of the crude sewage, as shown in Table No. 32, the septic tanks remove very little suspended matter since that deposited during an especially low sewage flow is generally scoured out during the higher flows obtaining during wet weather. Results obtained on the third detailed examination of the plant in the spring of 1907 showed such low efficiency in the case of the septic tanks that in conjunction with the short period of flow, advice was given to the village officials as to the desirability of enlarging the tanks. At the present time (Dec., 1907,) the Ashland septic tanks have not been enlarged. but some preliminary excavation has been made looking to a future extension of the tanks.

On the examination of July 11-12, 1906, no dissolved oxygen was found in the effluent of the septic tanks, although small quantities were present in the applied sewage. On the examination of April 24-25, 1907, however, considerable dissolved oxygen was present, as the following figures indicate:

TABLE NO. 31.

Dissolved Oxygen in the Applied Sewage and in the Effluent of the Septic Tanks on April 24-25, 1907.

Hour.	Temp. Deg. F.		Dissolved Oxygen. Parts Per Million.	
	Sew.	Eff.	Sew.	Eff.
8:00 A.	46	46	3.8	4.2
12:00 M.	48	47	3.6	3.6
4:00 P.	48	48	2.0	4.8
8:00 P.	48	47	1.7	0.0
12:00 P.	47	46	3.3	2.2
4:00 A.	47	47	4.3	4.9
Average	47	47	3.1	3.3

TABLE NO. 32.

Removal of Suspended Matter by the Combined Grit Chambers and Septic Tanks.

Date — 1906–07.	Suspended Matter.					
	Parts Per Million.				Percentage Removal.	
	Total.		Volatile.			
	Sewage.					
	Crude.	Septic.	Crude.	Septic.	Total.	Volatile.
July 11-12, 1906	72	50	44	.....	31	.....
November 16, 1906	194	175	113	95	10	16
April 24–25, 1907	47	70	34	55	—49	—62

SAND FILTERS.

When operated continuously, as was the practice before this plant was visited during this investigation, the effluent from the sand filters was unsatisfactory as it contained no nitrates, no dissolved oxygen and was slightly putrescible. As indicated by analyses collected during the first detailed examination of the plant, the effluent was of very poor quality, the filters themselves were seriously ponded and the surface filtering material was covered with a slimy blanket of organic matter which gave rise to decided odors. The results of the analyses of the samples of the effluents from the filters collected on the second examination, however, showed a greatly increased efficiency and an effluent which was stable and fully protected by nitrates and dissolved oxygen. In general terms, the efficiency of this plant has been high since it has received greater supervision and since the filters have been used in strict rotation. Advice as to the desirability of removing downspouts connections from the sanitary sewers acted upon by the village authorities in 1906 has tended materially to reduce the flow of sewage during storms, a feature which also has tended to improve the general efficiency of the plant. In conclusion it should be stated that at the present time the plant is to be classed as a successful example of intermittent sand filtration and that it must be considered as solving the local problem of disposing of the sewage of the village without nuisance. It is a pleasure to record that the Ashland officials have at all times heartily co-operated with the representatives of the State Board of Health.

COSTS.

The first cost of the plant was $5,000, including land. The total cost in 1906, including $1,380.48 for reconstruction and charging to the plant operation one-fourth of the health officer's salary, was $1,530.48, or 51 cents per person tributary. In 1907 the total cost of operation was $392.80, or 13 cents per person tributary. The expenses of 1907 include covering the septic tanks at a cost of $90.60, so that an annual average cost figure would be about $300.00. The several items of cost for the years 1906 and 1907 are listed in the following table and they do not include interest nor depreciation.

TABLE NO. 83.

Cost of Operation.

	1906.	1907.
Salaries	$150 00	$204 00
Extra labor	1,380 48*	88 20*
Repairs	.....	90 60†
Cleaning septic tanks December	.....	10 00
Total	$1,530 48	$392 80

1906 * Repairing underdrains, sanding trenches, leveling filters.

1907 * Plowing, March and October; mowing weeds; plowing, including also purchase of 32 feet of 24-inch channel pipe.

† Covering septic tanks.

TABLE NO. 34.

Results of Chemical Analyses.

Date 1906-'07.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.													
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.
					Organic.		Free Ammonia.	Nitrites.	Nitrates.							
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.				
Crude Sewage.																
July 11, 1906.....	6:00 A.-10:30 P.	60	18	.....	6.7	.....	11.5	0.03	0.0	33	90	55	24	.....	.....	.....
July 11-12, 1906...	11:00 P.- 5:30 A.	60	10	9.6	4.1	2.4	4.5	0.25	0.0	16	37	23	8	.....	.....	.....
Weighted Av'ge.....		60	15	.....	5.9	.....	9.2	0.10	0.0	27	72	44	19	.....	.....	.....
Nov. 16, 1906.....	6:00 A.-10:30 P.	51	34	.....	7.2	2.6	18.0	0.12	0.0	28	194	113	14	0.0	.....	41
April 24, 1907....	6:00 A.-10:30 P.	48	19	.....	8.8	.....	4.0	0.30	0.4	50	64	46	27	2.8	.....	25
April 24-25, 1907..	11:00 P.- 5:30 A.	47	11	.....	3.7	.....	3.5	0.05	1.5	31	13	9	8	3.8	.....	16
Weighted Av'ge.....		48	16	.....	7.1	.....	3.8	0.22	0.8	44	47	34	21	3.1	.....	22
Septic Sewage.																
July 11-12, 1906..	6:00 A.- 5:30 A.	61	22	.....	7.3	2.2	12.5	0.02	0.0	.....	50	.....	.....	.....	.....	.....
Nov. 16, 1906.....	6:00 A.-10:30 P.	51	22	.....	8.8	.....	18.0	0.14	0.0	.....	175	95	.....	0.0	.....	.....
April 24-25, 1906..	6:00 A.- 5:30 A.	47	19	.....	6.6	.....	4.2	0.20	1.2	.....	70	55	.....	3.3	.....	.....
Sand Filters.																
July 11-12, 1906...	7:00 A.- 6:00 A.	69	8	.....	1.7	.....	6.2	0.01	0.0	.....	10	.....	.....	.....	.....	.....
Nov. 16, 1906.....	6:00 A.-10:00 P.	44	11	.....	5.8	.....	8.0	0.05	2.0	.....	21	.....	.....	7.9	sl+	.....
April 24-25, 1907..	7:00 A.- 6:30 A.	48	16	.....	4.2	.....	3.8	0.10	5.0	.....	31	.....	.....	2.8	0	.....

GENEVA.

Geneva is a village in Ashtabula County, about five miles from the shore of Lake Erie. Cowles Creek, a stream of small flow, runs through the central portion. According to local opinion, the population of Geneva in 1906 was 2500. The village maintains a number of public improvements, comprising a public water supply and a system of sanitary sewers. The public water supply was installed in 1901 and is obtained from the Grand River, but is first filtered by mechanical filters before it is delivered to consumers. (See pp. 141-153.) According to the records of the water department, the daily consumption in 1907 ranged from 250,000 to 275,000 gallons.

SEWERAGE.

The sanitary sewers of the village were built in the fall of 1903. The system at the present time comprises about thirteen miles of gravity sewers for domestic sewage only. The main trunk sewer is 1.26 miles in length and consists of 10, 12, and 15-inch vitrified sewer pipe. The sanitary sewers are conducted to a point in the west central portion of the village where the sewage is purified. Owing to local topography, a number of the sewers are laid in 20-foot cuts; and although the sewers are all underdrained with 3 and 4-inch tile, yet the ordinarily high ground water level and the deep cuts in certain parts of the sewerage system cause the flow of sewage to be largely increased during wet weather. There are eighteen flush tanks in service, and these discharge from three to four times daily. Few roofs are said to be connected to the sanitary sewers, but considerable storm water is admitted to the system. Another feature which tends to increase the flow of sewage during wet weather is the fact that the electric railway in the main street has raised the general grade so that the manhole covers are now slightly depressed and act as small basins for surface water.

At the end of 1907 there were about 270 connections to the sewers, the greater part of which are said to be for sanitary purposes; and from this fact, the population served is estimated at 1,200, or about 50 per cent. of the total population. Very little industrial waste enters the sanitary sewers, and the sanitary wastes from three hotels, twenty-one business blocks, two school houses with a total estimated population of 700, and one factory employing from 150 to 200 men, comprise practically all of the connections to the sanitary sewers other than those which are strictly residential.

Very few storm drains have been constructed, as the greater part of the storm water is carried off by natural watercourses leading to Cowles Creek.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In 1902 the question of providing a system of sanitary sewers for the village was first discussed, and it was early recognized that such a system should provide for sewage purification because of the small flow of Cowles Creek and the serious pollution which would result were the sewage of a village of 2,500 persons to be discharged into this stream without treatment. Forthwith, a sanitary engineer was engaged to prepare plans for the sewering of the village, and in January, 1902, sketch plans were presented to the State Board of Health for approval. The plans provided for a separate system of sanitary sewers and a sewage purification plant located in the northern part of the village and consisting of a septic tank and intermittent sand filters. The general plans were approved by the Board on condition that no construction should take place until

full detailed plans were presented. New plans in detail were subsequently submitted, and in place of intermittent filters there were substituted contact filters of artificial construction. These filters were to be preceded by a storage reservoir and a septic tank from which the sewage was to be pumped. The contact filters proposed were six in number with a total area of 0.43 acre, and were to be constructed of clean lake sand or sharp bank gravel. The pumping station and the contact filters were to be located on opposite sides of Cowles Creek.

The State Board of Health approved these plans in March, 1902, but the actual work of construction was not carried out until the fall of 1903. The plant as constructed was changed materially from that which had been approved, and as it existed during this investigation was virtually constructed without the official approval of the State Board of Health. In its present state the plan comprises a septic tank, a storage reservoir, a pumping station housing two centrifugal pumps and two gas engines, and artificial sand filters to which the settled sewage is applied in turn by plural alternating siphons.

EXAMINATIONS AND INSPECTIONS.

This plant was visited on seven occasions. Detailed examinations were carried out on June 21-22, 1906, and June 24-25, 1907. The remaining visits were inspections made on May 24 and December 21, 1906, and on June 12, August 22, and October 18, 1907, respectively.

DESCRIPTION OF PLANT.

The plant is located on a 10-acre tract of land, close to the built-up portion of the village. One of the main residence streets is within only 200 feet of the pumping station and septic tank. Cowles Creek separates the septic tank, reservoir, and pumping station from the sand filters, which are located on the east side of the stream some 1000 feet distant.

Grit Chamber.

The crude sewage reaches the plant through two main sewers 12 and 15 inches in diameter, respectively; these merge at a manhole directly in front of the grit chamber and septic tank. The sewage receives no screening but discharges directly into a grit chamber which is merely a part of the septic tank. It is about 8'-8" x 13' in plan and 8'-8" deep to the flow line and has a capacity of about 7,500 gallons. There are no means of controlling the rate of flow, which depends upon the quantity of sewage reaching the plant. (The location and further details of the grit chamber are shown on Plate XXVII.)

Septic Tank.

Passing from the grit chamber, sewage is discharged into the septic tank which is of concrete, built entirely underground. The bottom is located 18 feet below the natural ground level. The tank dimensions are 46'-1" x 13' in plan and 8'-8" deep to the flow line; its capacity is about 39,000 gallons. The walls are 16 inches thick and the bottom is 6 inches thick. The septic tank and the adjacent reservoir as well are entirely in excavation and are covered with an arched roof of concrete 12 inches thick. From the normal flow line of the septic tank to the crown of the roof there is a head room of 5 feet 2 inches. A 30-inch manhole located at the inlet end allows entrance to the septic tank. The top of the roof is back filled to the original ground elevation and is seeded. Ventilation through the roof is

effected by two 10-inch openings which extend to a height of 5 feet above the top of the roof and are provided with ordinary flue caps.

Inlets and Outlets. The sewage flows from the grit chamber through five inlets consisting of a number of 8-inch openings in a brick wall which separates the grit chamber and the septic tank. On the septic tank side of the wall the openings are 4" x 8" in area. The openings are equally spaced across the tank and are at mid-depth of the flow line. The construction and location of the inlets will probably be clearer from a reference to the sectional drawing shown on Plate XXVII. At the outlet end of the tank the sewage discharges into a shallow concrete culvert whence it passes through two 15-inch channels 8 inches high into the storage reservoir adjacent to the septic tank.

Baffles. The septic tank is baffled by a wooden scum baffle located at the outlet and extending across the tank 24 inches below the flow line. A surface baffle located 23 feet from the inlet of the tank is also provided, and it also extends 24 inches below the flow line.

Sludge Drain. The floor of the tank is level. Provisions for removing sludge are made, however, by means of an 8-inch gate valve connected by an 8-inch pipe to the suction of the centrifugal pumps and located in a sump at the inlet end of the septic tank. The sump in the septic tank is connected with a similar one in the grit chamber and allows the removal of sludge by pumping from either one or both tanks. The pumps are primed with water from the village mains. The supernatant sewage in the septic tank may be discharged either into the creek or on to land.

Method of Control. There is no method of controlling the rate of flow through the septic tank, other than the effect of the varying rate of sewage flow.

By-pass. In the manhole directly in front of the grit chamber and septic tank a by-pass is provided whereby it is possible to discharge the crude sewage directly to the creek. The pipe connection from the septic tank and storage reservoir is also so arranged that the sewage may be pumped to the creek or to a strip of land on the east side of the creek in case occasion demands.

Aerating Devices. No provisions are made for aerating the septic sewage, although when the water is low in the reservoir some aeration is effected in the passage of the sewage from the septic tank. Furthermore, subsequent pumping from the dosing tank, no doubt, tends to aerate the sewage to a certain extent.

Measuring Weirs. No permanent weirs are provided. By rating the pumps it is possible to obtain an approximate estimate of the sewage flow.

Special Features. To provide facilities for inspecting the septic tank, there is a wooden platform or walk 24 inches wide, constructed of 2-inch lumber and hung on two iron stirrups, the ends resting on a cored brick wall, which, respectively, serves as the inlet and outlet of the septic tank. The walk extends from the foot of the manhole located over the grit chamber to the extreme end of the septic tank. Inspection is by this means greatly facilitated.

Storage Reservoir.

Adjoining the septic tank is a storage reservoir, 13' x 63'-2" in plan and 14'-6" deep to the crown of the concrete arched roof. The reservoir is of concrete and its construction is the same as that of the septic tank. Entrance to the reservoir is afforded by a manhole at the outlet end opposite the discharge from the septic tank. A concrete platform is provided at the foot of the manhole.

At the outlet end is a 24-inch sump which serves as a suction for the centrifugal pumps when sewage is being pumped from the reservoir to the filters across

the creek. The reservoir and septic tank are similarly located, as indicated by Plate XXVII.

Sludge Disposal Area.

No area is provided for the disposal of sludge should the cleaning of the septic tank become necessary in the subsequent operation of the plant.

Pumping Plant.

As before stated, the final step in the purification of the Geneva sewage is carried out on intermittent sand filters, which are located on the opposite side of the creek from the septic tank and reservoir. To operate the filters it was necessary to provide a pumping plant, owing to the unusual depth at which the sewers are laid. As installed, the plant comprises two centrifugal pumps with an 8-inch suction and 6-inch discharge, belted to two 8 H. P. gas engines. The pumps and engines are in duplicate and are readily interchangeable. The engines are operated with natural gas. The head against which the pumps work is 25 feet. The pumps and engines are located in a wooden frame building 12′ x 18′ in plan, adjacent to the septic tank and reservoir.

Dosing Tank and Automatic Apparatus.

The centrifugal pumps discharge through a 6-inch force main to a dosing well located about 1,000 feet distant on the east side of Cowles Creek. This tank is 20′-6″ x 11′-6″ in plan and 3′ deep. The working depth is 2′-6″, and the capacity is 4,400 gallons. The tank is constructed of 6-inch concrete floors and brick walls 16 inches thick, and is covered with a wooden superstructure. The apparatus for automatically rotating the discharge of sewage to the six sand filters in turn, comprises six plural alternating 10-inch Miller siphons. In addition to the main siphons, there are provided auxiliary siphons constructed of 1¼-inch galvanized iron pipe and located in a central concrete chamber divided into six water-tight triangular compartments which are 3 feet 3 inches deep. During a discharge, these auxiliary siphon wells are completely submerged. The individual wells are connected by means of 1¼-inch pipe to the bell of the siphon opposite, and are cross connected by means of the auxiliary siphon to the long leg of the siphon following. The discharge from this apparatus takes place through from 10 to 30 feet of 10-inch pipe, according to the position of the several filters, details of which are shown on Plate XXVIII.

Owing to certain errors in construction, the automatic apparatus, just described, has not proved itself to be entirely satisfactory in rotating the discharge from one filter to the next. In view of this fact, in October, 1907, arrangements were made with the Pacific Flush Tank Company for the modification of the original design of the apparatus to include all of the features which are embodied in a type of automatic dosing apparatus which contains improvements suggested by the performance of the original design, of which the Geneva apparatus may be said to be a type.

The apparatus as modified contains 8-inch air domes in place of the straight 1¼-inch auxiliary siphons, and is further provided with valves and cut-offs so that any filter or filters may be placed out of service at the will of the operator. Plate XXVIII. shows in part the details of the modified apparatus. The theoretical depth of draw is, as before, 2 feet 6 inches.

Filters.

The septic sewage pumped from the storage reservoir and received in the dosing well containing the automatic device, just described, is intended to be

discharged in rotation on to the intermittent sand filters of artificial construction. These filters are six in number and are 67 feet square. Each unit contains 4,500 square feet and the total available area of the entire plant is 0.62 acre. These filters are arranged symmetrically with the dosing device in the center.

Filtering Material. All of the filtering material used in construction was hauled to the site of the filters. The sand was obtained from Lake Erie, a haul of about five miles, and the gravel from a local bank at a short distance from the plant. The filtering material, generally speaking, comprises lake sand, sharp gravel and clayey gravel. The size and depth of the several layers of the filtering material vary in the different filters, and on this account they are shown in tabulated form as follows:

TABLE NO. 35.

Kind, Size, and Depth of Filtering Material.

Filter Nos.	1	2	3	4	5	6
Sand	2	2	2	2	2	2
Sharp lake gravel	.....	10	7	.....	.....	.....
Clayey gravel	46	36	39	46	46	46

Size.

	Effective Size.	Uniformity Coefficient.
Sand	0.28 m.m.	1.6
Sharp lake gravel	0.41 m.m.	2.4
Clayey gravel	0.63 m.m.	3.0

In the latter part of 1907, as discussed beyond, the plant was resanded and the depth of surface sand increased to an average of 5 inches. The sand used was obtained from Lake Erie and had an effective size of 0.35 m. m. and a uniformity coefficient of 1.9.

Underdrains. The six filters are underdrained with 6-inch lateral drains of vitrified sewer pipe leading to a 6-inch main drain which is laid on a 1 per cent. grade. This main drain gradually increases in size to 8 and 10 inches and discharges at the effluent manhole on a 2 per cent. grade. Manholes are provided at each change of grade of the main drain, as shown on Plate XXVIII. The underdrains are laid with open joints and the lateral lines are 20 feet apart on a minimum grade of 1 per cent. At the end of each line of lateral drains, 6-inch pipes are carried to the surface of the filtering material for the purpose of ventilating the underdrains; three of these lantern holes are provided for each unit. No special coarse material is used in the construction of the underdrains.

Distribution Devices. The discharge from the 10-inch plural alternating siphon is conducted through 10-inch pipe to the corner of the filters, where the pipe is supported in a concrete cradle capped with stone.

On the filters themselves there are provided wooden sluices of ¾-inch lumber. The largest section is 10" x 16", decreasing to 6" x 8". Three-fourth-inch holes, 3 feet on centers, pierce the bottom of the distributors, at which points strips of board 6 inches wide have been placed to prevent the disturbance of the sand during the discharge of a siphon. The distributors are from 6 to 8 inches in depth. They are arranged starting from either the center or corner of a given unit so as to cover thoroughly the entire filter by lateral branches from the main line.

Effluent Discharge. The filters discharge by gravity into the main underdrain already described. From a manhole located at the lower end of the drain, the purified sewage passes through 180 feet of 10-inch pipe to Cowles Creek. No provisions are made to protect the plant from floods by back flooding gates or other devices at the outlet. It is understood, however, that at no time since the plant has been operated has there arisen a possibility of damage from high water.

SEWAGE FLOW.

Gagings of the sewage flow during dry weather were made on the two detailed examinations. In June, 1906, the average rate of sewage flow was about 181,000 gallons in 24 hours or 151 gallons per capita; in June, 1907, the average flow was 204,000 gallons or 170 gallons per capita. This high per capita flow during dry weather suggests a large volume of strictly ground water and such has been indicated at all visits during this investigation.

From September to October, 1907, daily records have been kept at the plant of the depth of sewage in the storage reservoir before and after pumping. These data, together with other information available from this investigation, allow an approximation of the daily sewage flow for a considerable period. Roughly estimated from the total hours of pumping, the quantity of sewage flow based on the average discharge of the pumps has ranged during the above period from 138,000 to 450,000 gallons in 24 hours, and averaged about 194,000 gallons. The latter quantity clearly illustrates the effect of storms and wet weather on the sewage flow.

COMPOSITION OF CRUDE SEWAGE.

The effect of ground water leakage and in general the high per capita sewage flow naturally implies a highly diluted crude sewage. Weighted average analyses covering a full 24 hour period were collected on each detailed examination. As usual these samples were divided into day and night portions, respectively. There was comparatively little difference in the general character of the sewage as shown by the analyses of the two years. The crude sewage contains dissolved oxygen and nitrates and is very low in organic matter. The sewage has generally shown no evidence of colloidal matter and the suspended matter is granular and subsides rapidly. Analytical data with reference to the composition of the crude sewage may be found in Table No. 38.

OPERATION.

The Geneva sewage purification plant is in charge of the sewer committee of the village council. The actual operation of the plant is in charge of one man who is a licensed stationary engineer. Sewage from the storage reservoir is pumped daily to the dosing tank where it is automatically discharged on to the six filters in turn.

Pumping Plant.

During dry weather, the sewage flow of the village for a period of 24 hours is pumped from the storage reservoir to the purification plant during an average daily period of 7 to 8 hours. It is customary to pump for about three hours in the morning, afternoon and early evening, respectively. The actual pumping period, of course, varies with weather conditions. Generally it has been the practice to empty the well completely so as to afford sufficient storage for the high flow of sewage. One-half of the power plant is used at one time. The fuel is natural gas, which is obtained at a cost of 25 cents per 1,000 cubic feet in the summer and 30 cents in the winter. The daily records kept during September and October list the quantity of gas used daily for the month of September, 1907, this average was 768 and for the month of October 835 cubic feet. The range during these months was from 600 to 1,000 cubic feet per day. The corresponding pumping periods ranged from a minimum of 4.1 to a maximum of 16.7 hours and averaged 7.4 hours.

Grit Chamber, Septic Tank and Storage Reservoir.

Since the plant first went into service, the septic tank has not been cleaned and practically no attention is necessary save for the occasional removal of scum from the board walk. The grit chamber has not required cleaning and in fact the preparatory treatment of the Geneva sewage has been in entirely successful operation with practically no attention. Inspections of the septic tank made during this investigation have shown but little deposit of sludge and varying quantities of soft scum. Apparently, considerable suspended matter once deposited has passed out of the tank as it was found that a number of the small outlets, together with a part of the outlet weirs were in part clogged with sludge.

Under normal operation, the septic effluent is pumped from the storage reservoir into the dosing tank which floods the sand filters. During 1906, the operator of the plant was especially negligent and evidence is strong that the septic sewage was pumped directly to the creek. Direct pumping to the creek has not been necessary in 1907 since a new operator was engaged in April, but repairs to the automatic dosing siphons during the summer of 1907 necessitated the direct pumping of the septic sewage on to bottom land adjacent to the sand filters. Ordinarily, when the storage reservoir is emptied in the early evening, the flow from that time until 6:00 o'clock A. M. can be stored in the reservoir. During especially wet weather, however, sewage backs up through the septic tank and main trunk sewer and covers the board walk to a depth of a foot or more. Based on the average flow on the examination of June 21-22, 1906, the period of flow in the septic tank is 5.2 hours and the linear velocity is 0.74 m. m. per second.

Automatic Dosing Devices.

The six plural alternating siphons provided to flood the six sand filters in rotation have been in part out of service during the summer months of 1907. In November, 1907, they were in part reconstructed and since that date have been in successful operation. They received practically no attention up to the time the design was somewhat modified. When operating normally, the siphons draw 30 inches of sewage from the dosing tank. Including in the actual capacity of this tank the quantity of sewage pumped during the five minutes usually required to discharge the tank, the average volume of sewage per dose is about 6,600 gallons.

FILTERS.

Prior to this investigation and until practically the first of April, 1907, very little attention was paid to the operation of the filters and in fact the Geneva sewage plant received no attention other than that necessary to pump the sewage. The filters were neglected, the surface of the sand became coated with suspended matter, weeds and moss developed and the general appearance of the plant was very poor. The automatic flooding of the filters of course obviated daily attention, but beginning with this investigation the filters were raked and cleaned from time to time. Since April, 1907, the present operator has maintained the filters in good condition, the plant has been cleaned, weeds have been removed and its general tone has been greatly improved. The actual operation of the sand filters during 1907 comprises practically weekly rakings, as otherwise the final purification is essentially automatically effected. The rates of filtration are approximately 292,000 gallons per acre in 24 hours based upon the average sewage flow of 181,000 gallons in 24 hours. The estimated population served by the plant corresponds to the high population load of 1940 persons per acre. It is somewhat doubtful whether all the sewage from this population reaches the plant for it is probable that some of the taps to the sanitary sewers are not used at all for domestic wastes.

EFFICIENCY.

The Geneva sewage plant is located so near the residence portion of the village that odors would be at once noted. There has been no nuisance attributable to this cause nor have complaints arisen at any time since it was placed in service. The weakness of the raw sewage due to leakage may be a partial explanation of the lack of odors from a plant located so near residence property.

SEPTIC TANK.

The thoroughly covered septic tank has been operated without attendant odors and no removal of sludge has been necessary. In the removal of suspended matter its efficiency on an average has not been great. The fact that sludge has not accumulated in the tank suggests that suspended matters are carried away by the effluent. Analytical data obtained on the two detailed examinations with reference to the efficiency of the septic tanks indicated that the removal of suspended matter was —8 and —74 per cent. It is to be noted in this connection that the sewage is weak, that the suspended matters are normally low and that while they subside rapidly they readily lend themselves to putrefaction and when carried to the surface of the tank in part escape with the effluent.

The dissolved oxygen in the dilute crude sewage was not removed by the septic tank as indicated by the following results obtained in the examination of June 24-25, 1907.

TABLE NO. 36.

Dissolved Oxygen in the Crude Sewage and in the Effluent of the Septic Tank on June 24-25, 1907.

Hour.	Temp. Deg. F.		Dissolved Oxygen—Parts Per Million.	
	Sew.	Eff.	Sew.	Eff.
12:00 Md.	54	.....	3.2	.....
4:00 A.	56	.....	3.3	.....
8:00 A.	55	55	1.7	.....
12:00 M.	58	.....	1.6	2.0
4:00 P.	57	59	1.9	1.4
8:00 P.	56	.....	1.7	.....
Average	56	.....	2.2	.....

FILTERS.

On practically all the visits the effluent from the filters when in operation was excellent. Data are available from the first detailed examination and they show that the average effluent was well nitrified, was without odor and was low in organic matter. The condition of the filters, however, suggested that it would be desirable to increase the depth of the filtering material as it was found difficult to rake the surface for the removal of weeds and suspended matter. The resanding finally carried out during the summer of 1907, as already related, at once remedied this difficulty and at the same time tended to increase the efficiency of the filters. The filters were practically out of service on the second examination and hence no effluent samples were collected. Instructions, however, were left regarding the matter and on November 21, 1907, after the filters had been resanded and with the remodeled dosing devices in full successful operation, a sample was collected and was shipped to the laboratory. The analysis of this sample showed a remarkably high degree of purification, an effluent which contained 12 parts per million of nitrogen as nitrates and very small quantities of organic matter.

The success of these intermittent sand filters has depended almost entirely on the operation of the automatic dosing devices. When these clogged in the spring of 1907, due to lack of attention on the part of the caretaker, sewage was applied to perhaps two or three of the six units only and the filters soon ponded and no doubt produced an unsatisfactory effluent. With the automatic devices in proper condition sewage even in cold weather would disappear from the sand very rapidly. No difficulties were experienced in freezing weather as the temperature of the sewage has generally been sufficiently high to melt its way through the snow and ice.

SUMMARY.

The purification of the sanitary sewage of Geneva is accomplished successfully with no attendant odors and at low operating costs, as will be discussed presently. The septic tanks have been operated with little difficulty and with no

expense. The efficiency of the plant on the whole has been good, but during 1906, the plant was badly mismanaged, considerable crude sewage was by-passed and the entire plant was allowed to deteriorate. The neglected condition of the plant was brought out by this investigation and at its close a remodeled dosing device has been installed and the sand filters have been covered with 5 inches of clean lake sand placed with a view to rendering easier the operation of this part of the plant. Information from the city officials indicates that in the fall of 1907, after all these improvements and changes have been made under the efficient management of the present operator, the plant has been greatly improved and as analyses indicate, the effluent is all that could be desired.

COSTS.

The bond issue to provide for the construction of a system of sanitary sewers and for a sewage purification plant was about $48,000. Of this amount the trunk and lateral sewers cost about $34,800 and the purification plant including the pumping station, reservoir and filters cost about $13,500. The several items of cost were as follows:

Trunk sewer	$9,148 19
Lateral sewers	25,400 00
Purification plant	13,487 50
Total	$48,035 69

The ordinary operating costs prevailing during the latter part of 1907 were the labor of one man, cost of fuel and supplies. In 1906, the operation of the plant cost $611.24, a figure which includes the salary of the caretaker, a small amount of extra labor, fuel and engine supplies. In April, 1907, a new caretaker was engaged at a salary of $50.00 a month and a considerable sum was spent for repairs and renewals. The total cost for 1907 was over twice that for 1906 or $1,394.72. Of this amount $370 was used for resanding the plant at a cost of $1.33 per cubic yard, exclusive of the necessary labor which was $123.37 or a total cost per cubic yard in place of $1.77. Alterations in the dosing device were made at a cost of $231.25 and the pumping station was insured at an annual cost of $15. Considerably more gas was used corresponding to more faithful and efficient operation. The several items of costs for the two years are listed in the following table. The annual costs per person tributary were, in 1906, 51 cents, and in 1907, $1.16. On the basis of a caretaker at $50 a month, gas at $7 per month, supplies at 50 cents, and insurance at $15 per year, an average yearly cost of operation would be about $700, 58 cents per capita, or $9.60 cents per one million gallons of sewage treated.

This plant furnishes interesting information as to the cost of pumping sewage with gas engines. Based on the average gas consumption per day of 800 cubic feet at an average cost of 27½ cents per 1,000 cubic feet and the average daily sewage flow of 200,000 gallons, the daily cost including salary of the operator is about $1.92 or 39 cents per million gallons raised one foot high.

TABLE NO. 37.

Expenses for the Years 1906 and 1907.

	1906.	1907.
Salary, caretaker	$465 00	$560 00
Extra labor	88 01	123 37
Gas	53 25	89 50
Oil and supplies	4 98	5 60
Sand and gravel, 278 cu. yds	.....	370 00
Repairs	.....	231 25
Insurance	.....	15 00
Total	$611 24	$1,394 72

TABLE NO. 38.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.													
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.
					Organic.		Free Ammonia.	Nitrites.	Nitrates.							
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.				
							Crude Sewage.									
June 21, 1906.....	6:00 A.-10:30 P.	54	17	16	5.5	0.8	3.5	0.24	0.2	22	60	41	16	.....	.....	.....
June 21-22, 1906..	11:00 P.- 5:30 A.	52	13	11	6.4	1.3	1.0	0.12	1.0	19	66	39	7	.....	.....	.....
Weighted Av'ge.....		54	16	13	5.8	1.0	2.7	0.20	0.5	21	62	40	13	.....	.....	.....
June 24, 1907.....	6:30 A.-10:00 P.	57	13	11	4.8	2.8	5.2	0.30	0.0	36	99	44	48	1.7	.....	14
June 24-25, 1907..	10:30 P.- 6:00 A.	55	11	5.5	3.7	1.3	2.3	0.30	2.0	27	69	21	39	3.3	.....	12
Weighted Av'ge.....		56	12	9.2	4.4	2.3	4.2	0.30	0.7	33	89	36	45	2.2	.....	13
							Septic Sewage.									
June 21-22, 1906..	5:22 A.- 5:36 A.	54	13	.....	5.2	0.9	3.6	0.26	0.0	.....	67	41	.....	.....	.....	.....
June 24-25, 1907..	7:30 A.- 8:30 A.	57	7	.....	5.4	.....	4.6	0.70	0.0	.....	155	69	.....	1.7	.....	.....
							Effluent Sand Filters.									
June 21-22, 1906..	6.00 A.- 5:30 A.	58	4	.....	1.1	.....	0.8	0.08	8.0	.....	42	35	.....	7.4	0	.....
Nov. 11, 1907.....	Chance sample.	.....	3	.....	1.5	.....	0.1	0.00	12.0	.....	5	.....	.....	.....	0	.....

SHELBY.

The village of Shelby is in Richland County on Black Fork Creek, the headwaters of the Muskingum River, at a point where the stream has a watershed of about 40 square miles. The population of the village in 1907 is locally estimated at 6,000. A number of public improvements have been inaugurated to date. A public water supply was provided in 1897 and comprises a system of driven wells from which the excess of iron is removed by a process of aeration followed by filtration through pressure filters. The daily water consumption of the village is about 893,000 gallons, and of this about 223,000 gallons are stated to be used by railroads. A number of streets have been improved and there are now 11.25 miles of pavement, of which 5.25 miles are asphalt block and the remainder, 6 miles, macadam.

SEWERAGE.

Sanitary sewers and storm drains were installed in the village during the years 1899 and 1900. Those for sanitary purposes lead to a trunk sewer which extends about three miles north of the village and terminates at a sewage purification plant. The sanitary sewers in 1907 comprised about 25 miles of pipe sewers which range in size from 8 to 18 inches. There are at present about 350 connections to the sanitary sewers which serve an estimated population of 1,600. Since about August, 1906, practically no manufacturing wastes have entered the Shelby sewers, although prior to that date acid iron wastes of greater or less strength have been admitted to the city sewers to the marked detriment of the sewage plant. (For a full discussion of the acid iron wastes at Shelby see pp. 763-771). Six of the larger industrial establishments are, however, connected to the sewers for sanitary purposes. The estimated population, thus served, is 485.

While the Shelby sewers are primarily intended for domestic sewage, there are a large number of roof connections, and the sewage flow is, furthermore, largely increased during wet weather by the infiltration of ground water. This latter condition may be said to obtain during the greater part of the year.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In 1900, when plans were prepared for the system of sanitary sewers, it was considered necessary to provide for the purification of the sewage of the village in view of the fact that the only available means of disposing of the sewage by dilution was its discharge into Black Fork Creek. This stream during dry weather has a flow of only 1 to 3 cubic feet per second and were the sewage of the village discharged into this stream without purification, undoubtedly there would be created a decided nuisance and the waters of the stream could no longer be used for watering stock.

Accordingly, plans for sewage purification were prepared and were submitted to the State Board of Health, which approved the plans of 1897. The plans as presented provided for the purification of the sewage by intermittent filtration through filters constructed of cinders and gravel, preceded by small setlling basins or sludge pits and two large reservoirs which have a nominal capacity of about five days' flow.

EXAMINATIONS AND INSPECTIONS.

Detailed examinations were made in 1906 on July 5-7 and Nov. 14; in 1907, on July 25-26. Inspection visits were made on April 23, 1906, and in 1907 on July 31 and October 14.

Shelby. — General View of Filters.

Shelby. — Sludge Pit.

DESCRIPTION OF PLANT.

The Shelby sewage purification plant is about three miles north of the village on a 25-acre tract of land, which adjoins the Big Four Railroad. The surrounding country is but sparsely inhabited and the nearest house is 1,000 feet distant. (See Plate XXIX.)

Settling Tanks.

The sewage from the 18-inch trunk sewer flows first into one of two brick settling tanks or sludge pits as they are locally called. Each tank is 10 x 24′ in plan and 6′-6″ deep and at the inlet and 5 feet deep at the outlet; the depth to the flow line ranges from 3 feet 6 inches to 5 feet, and averages 4 feet 3 inches. The average capacity of each tank is 7,700 gallons. The tanks are covered with a hinged board flat roof 25′-4″ x 11′-4″ in area. This roof forms a tight covering but may readily be raised for purposes of inspection.

Inlets and Outlets. The raw sewage enters each settling basin through a 15-inch vitrified sewer pipe, with its invert located 18 inches below the top of the brick wall, and hence has a free discharge into the tank.

The outlet is a 15-inch vitrified pipe, similarly located with respect to the flow line of the tank.

Baffles. No special means are provided to control currents or eddies by means of baffles.

Method of Control. No means are provided for controlling the rate of flow which depends entirely on the volume of sewage.

By-pass. A manhole is provided on the 18-inch trunk sewer line as it enters the plant and a Y, controlled by a wooden gate, permits the discharge of the entire volume of sewage without treatment.

Aerating Devices and Measuring Weirs. There are no facilities for aeration and no permanent means are available for measuring the sewage flow.

Subsidiary Sedimentation.

Further sedimentation is provided for by means of two reservoirs excavated in the natural earth. One has an area of two acres and a depth of about two feet (approximately 1,300,000 gallons capacity); the other has an area of about 24,400 square feet or about 0.56 acre (approximately 360,000 gallons capacity). These reservoirs, which are merely rough excavations, are provided with 8-inch overflow pipes which lead to the Black Fork. The main or west reservoir also contains an outlet direct to the Black Fork. This outlet is kept closed by a roughly constructed wooden gate, except when it is desired to empty the reservoir for cleaning. The reservoirs are connected by means of 15-inch tile which form a pipe culvert under a drive way which separates the two reservoirs.

New Sludge Pit.

In the spring of 1907, to provide further area for the sedimentation of the sewage and with a view to confining the deposition of sludge to as small an area as possible, a part of the west reservoir was separated by means of wooden piling. The settling tank or sludge pit thus formed is 60′ x 20′ x 2′-7″ average depth and has a total capacity of 23,500 gallons. The division from the main reservoir is effected by means of 6-inch plank, 2 inches thick, the ends of which are sunk 18 inches into the soil. The ends and the side at four points are tied with twisted iron wire. The sewage is caused to discharge through a 25-inch rectangular opening 6 inches deep and located at the end of the tank opposite the inlet.

Sludge Disposal Area.

The accumulation of sludge in the so-called "sludge pit" and in the reservoir when removed, as occasion requires, is discharged on to an adjacent portion of the farm and is eventually plowed under. No special area is set aside for this purpose.

Filters.

The purification devices proposed comprise two filters, one 10,000 square feet in area and the other 15,000 square feet; the total area is 0.57 acre. The filters and reservoirs are separated by 10-foot earth embankments.

Filtering Material. These filters are prepared from the natural soil by constructing depressions in the natural clay, twenty feet apart. Over each depression is placed a 6-inch layer of gravel from 6 to 8 feet wide. Over the entire filter there is then laid a layer of cinders 18 inches thick. The total depth of the filtering material is 2 feet over the underdrains and 18 inches mid-way between them. The main filtering material proper, therefore, comprises cinders which have an effective size of 0.24 m. m. and a uniformity co-officient of 18.7.

Underdrains. The underdrains consist of a main 8-inch drain and 6-inch laterals, and are constructed of vitrified sewer pipe with butted joints wrapped with cheese cloth. They are laid in depressions 20 feet apart. At the end of each drain and extending 6 inches above the filtering material, there is a 6-inch pipe inclined at a slight angle, intended to effect the ventilation of the underdrains and to prevent the flooding of the plant in case of very high sewage flow. As already mentioned, coarse gravel is placed on the lower layer of the filtering material but frequent cleanings have long since intermixed the cinders and gravel.

Dosing and Distribution Devices. No special devices are in use for flooding the filters which receive the continuous flow from the reservoirs. Sewage from the second reservoir flows on to four lines of 15-inch half tile pipe placed about twenty feet apart. These tile convey the sewage to the filter farther distant from the second reservoir. In addition, four lines of 8-inch tile pierce the dividing embankment between the reservoirs and filter No. 1 and distribute sewage on to this filter at its north side.

Effluent Discharge. The effluent from the filters flows by gravity through about 350 feet of 8-inch vitrified pipe which leads to the Black Fork. The plant is so situated with respect to this stream that it is entirely inundated during high water.

SEWAGE FLOW.

The rate of sewage flow was obtained from weir measurements on each of the detailed examinations. The first and third examinations were of 24 hours duration, and the second was 12 hours. On the first examination the average, maximum and minimum rates of flow, under dry weather conditions, were 238,000, 352,000 and 137,000 gallons in 24 hours respectively; the last represents the night flow. On the third examination there was a greater infiltration of ground water and the average maximum and minimum rates of flow were, respectively 351,000, 544,000 and 307,000 gallons in 24 hours. The 12-hour examination from 10:00 o'clock A. M. to 10:00 o'clock P. M. showed an average rate of 393,000 gallons. The flow per person tributary on the first and third detailed examinations was 149 and 219 gallons, respectively. Prior to the summer of 1906, the sewage flow at Shelby included about 25,000 gallons of acid iron wastes from the steel tube works. The high night flow, due chiefly to ground water leakage, is illustrated by the 24 hour gagings carried out on July 25-26, 1907.

TABLE NO. 39.

Percentage Which Flow at Different Hours of the Day and Night is of the Average on July 25-26, 1907.

Hour.	Rate of Flow Gals. in 24 hours.	Percentage of Average.	Hour.	Rate of Flow Gals. in 24 hours.	Percentage of Average.
10:00 A. M.	352,000	100	10:00 P. M.	397,000	113
11:00 "	397,000	113	11:00 "	352,000	100
12:00 "	545,000	155	12:00 "	352,000	100
1:00 P. M.	421,000	120	1:00 A. M.	352,000	100
2:00 "	306,000	87	2:00 "	306,000	87
3:00 "	306,000	87	3:00 "	306,000	87
4:00 "	352,000	100	4:00 "	306,000	87
5:00 "	306,000	87	5:00 "	306,000	87
6:00 "	397,000	113	6:00 "	306,000	87
7:00 "	306,000	87	7:00 "	306,000	87
8:00 "	306,000	87	8:00 "	352,000	100
9:00 "	306,000	87	9:00 "	397,000	113

COMPOSITION OF CRUDE SEWAGE.

The Shelby crude sewage has always shown a predominance of acid iron wastes until these wastes were removed in July, 1906. In view of the high sewage flow due to ground water infiltration, the crude sewage is very dilute and the greater part of the organic matter is in suspension and appears readily to be amenable to rapid sedimentation. When acid iron wastes were admitted into the sewers, the sewage was coagulated as it flowed to the plant and because of the presence of iron contained practically no dissolved oxygen and was substantially non-putrescible after subsidence. With the removal of the acid iron wastes, there was a gradual change in the sewage to that normal for those sewages which are largely diluted with ground water. The suspended matter is granular, no colloidal matter is in evidence and both dissolved oxygen and nitrates are present. The night flow is especially weak and consists chiefly of clean water.

The large quantity of iron in the crude sewage before the removal of the acid iron wastes and the subsequent change in this regard, is shown in the following table, in which also are interesting data with reference to the suspended matter in the crude sewage as found on the three detailed examinations. Even before the acid iron wastes were removed from the sewers, the sewage probably contained no free mineral acid as there was apparently sufficient alkalinity to neutralize the free acid of the acid rinsing liquors, although the sewage generally showed a high acidity due to iron salts.

TABLE NO. 40.

Iron and Suspended Matter in Shelby Crude Sewage Before and After Removal of Acid Iron Wastes.

Date — 1906-07.	Parts Per Million.			
	Iron (Fe).		Suspended Matter.	
	Day.	Night.	Day.	Night.
July 5-6, 1906	240	420	164	81
*November 14, 1906	62	.....	163	.....
July 25-26, 1907	4.0	4.5	42	41

* Acid iron wastes removed August, 1906.

OPERATION.

The street commissioner of the village is in charge of the plant and in the warmer months of the year visits the plant several times weekly. In the winter, the plant receives but little supervision and in case of heavy storms the filters are generally flooded by the waters of the creek. Several additional men are engaged from time to time when the sludge pits, reservoirs, and filters are cleaned. No pumping is carried out at this plant and its operation requires practically very little attention.

Sludge Pits and Storage Reservoirs.

Generally for a considerable period one sludge pit alone is in service. From this pit the sewage flows in turn into two reservoirs. The period of flow in the sludge pits is perhaps 30 minutes (linear velocity 4 m. m. per sec.) and in the reservoirs from 4 to 5 days. The principal attention necessary in the operation of the preparatory devices is the question of cleaning. During this investigation, it has been the practice to remove sludge from the various settling tanks and the filters at six month intervals. The plant was cleaned in June, 1906, October 1-15, 1906, but not again until from July 1st to August 6, 1907.

Heavy rains and the spring floods interfere greatly with the operation of the plant and the decided clogging which occurs in the filters for several weeks before the semi-annual cleaning, prevents the filtration of the entire sewage flow and results in by-passing the settled sludge through the overflows into the Black Fork.

Removal of Sludge from Pits. The method of cleaning the sludge pits was learned from the special visit made on July 31, 1907. The entire contents of the tank are first stirred with poles with a view to diluting the sludge so that it will readily flow. The mixed sludge and supernatant sewage are then raised into a tank wagon by means of a bucket conveyor, which consists of a series of half gallon buckets, which work over a 14-inch hand operated sprocket wheel. At the top of the path of the conveyor, the buckets discharge through a wooden trough into a tank wagon. The tank is 3 feet wide, 12 feet long and 2

Shelby. — Sludge Disposal, Showing Method of Cleaning Sludge Pit.

Shelby. — Discharge of Sludge from Tank Wagon.

feet 3 inches deep, and has a capacity of about 600 gallons. At the rear of the wagon there is a compartment 4 feet long, 14 inches deep, and 12 inches wide which contains openings at each end and at the center. The filled tank is hauled away by horses to the neighboring field, the wooden gate on the end is lifted and the sludge is discharged through the openings at both ends and at the center of the wagon. The tank wagon is kept in motion during the discharge of sludge and the latter is thus spread in thin layers over a considerable area. No odors were noted from the sludge, and the entire process may be said to be unobjectionable from this standpoint. The sludge rapidly dries and oxidizes and is eventually plowed in. The accompanying photographs illustrate the foregoing method of cleaning the sludge pits.

Method of Cleaning Reservoirs. The west reservoir which first receives the effluent from the sludge pits has always contained the greater part of the sludge. Interesting data were obtained as to the cleaning of this basin in the fall of 1906. When cleaned, the reservoir had been in service for four months. It was stated by the superintendent that 258 2-horse loads of sludge were removed from the basin, at a cost of about $96.00. The sludge was shoveled into wagons, one of which is said to have handled 30 loads per day. The work lasted from October 1st to October 15th, 1906. The wagons were discharged on to an adjacent hill about 50 yards distant from the reservoir. The sludge when first removed and when in a moist condition had a strong odor. The dry sludge, however, was without odor as it was probably fairly well oxidized. To prevent any complaints from odors, the sludge was covered with a thin coating of chloride of lime. It was stated that no objection was raised by the nearby farmers at any time during the progress of the work. In a moist condition, the sludge was of a black color, but on exposure to the air rapidly turned brown, and when examined some two months later the greater part of it had oxidized and showed stains of oxide of iron. A similar procedure was followed on the next cleaning in the summer of 1907 and conditions were practically similar, although there was less iron in the sludge and there was less deposited over the entire reservoir, owing to the use of the subsidiary settling basin, constructed at the conclusion of the cleaning of the west reservoir in October, 1906.

Filters.

Both filters are in use at one time. While the acid iron wastes were reaching the plant the filters were generally seriously clogged with iron at all times. Based on the average rate of flow of from 238,000 to 351,000 gallons in 24 hours, the rates of filtration have been very high and have ranged from 418,000 to 615,000 gallons per acre in 24 hours. The available area of filters corresponds to a load of 2,800 persons per acre. It has been the general practice to dig over the filters about once each year, but on the first examination it was found that the filters were decidedly clogged and that during the cleaning of the plant in June, 1906, while a certain quantity of the clogged material had been removed from the filters, yet they had not been dug over as is the general practice. The filters were so seriously clogged and the operation of the plant was so decidedly and adversely effected by the discharge of acid iron wastes into the sewers, that as a result of this detailed examination, the State Board of Health advised the village officials to forbid the further use of the sewers for this purpose, and at the same time took up with the tube works officials the question of other means for disposing of these acid iron rinsing liquors. On August 14, 1906, the wastes were removed from the sewers.

On the next visit on November 14, 1906, it was found that the entire plant and the filters had been cleaned, as already related, and that after the clogged

surface material was removed the filters were dug over 12 inches deep and were then leveled. The filtering material was found to be heavily stained with iron, and although decided clogging was in evidence, it was noted that the clogging did not extend to the underdrains. After this thorough cleaning, both filters were again placed in service and sewage passed through the sand practically as fast as it flowed to the filters.

The filters continued in service through the winter and spring of 1907, although occasionally out of service on account of floods, and were not again cleaned until July 31, 1907. On the detailed examination of July 25-26, 1907, it was found that both filters were operating at their maximum capacity and that the long period of service since a previous cleaning, even in the absence of acid iron wastes in the sewage, had resulted in such serious clogging that practically only one-half of the settled sewage was passing through the filters, and the remainder was flowing directly to the creek through the overflow from the reservoir. In view of this condition it was advised that the filters be cleaned at once, and that the sludge be removed from the pits and reservoirs. It was developed later that the filters uncovered slowly when drawn down for cleaning and when inspected on July 31, 1907, a coating of sludge one inch in thickness was noted on the surface of the filtering material. Considerable iron was noted in this deposit. The serious clogging of the filters under the high rates of flow which prevail at the plant, suggested that it is necessary to clean the filters at more frequent intervals than six months. The final inspection on October 14, 1907, indicated that the cleaning of the summer had greatly improved conditions and the filters were operating successfully and no sewage was flowing into Black Fork without purification.

EFFICIENCY.

Since first operated, a number of suits have been filed against the village of Shelby on account of the alleged pollution of the Black Fork by the effluent from the village sewage purification plant. The complainants have ordinarily claimed that the waters of the stream were polluted and rendered unfit for domestic uses and for the watering of stock, by the discharge from the plant of liquids containing large quantities of iron which specifically discolor the waters of the stream and render it incapable of supporting fish life. In June, 1906, however, a suit was filed on account of the asserted nuisance from odors arising from the alleged improper disposal of the sewage of the village.

The attention of the State Board of Health was brought to this matter and the assistant engineer made an investigation and reported "that the creek was in a polluted condition, due to a large extent to sewage sludge discharged from the bottom of the settling reservoir at the disposal works, and to the acid wastes from the tube works, which prevent the purification of the sewage." (Report of the State Board of Health 1906, p. 66). Shortly after this inspection there was made the first detailed examination of this investigation. This examination brought out several interesting and important points relative to the efficiency of the plant and the general effect thereon of the acid rinsing liquors from the tube works, and suggested that to improve the condition of the plant, the acid iron wastes should no longer be admitted into the village sewerage system.

Effect of Acid Iron Rinsing Liquors and Desirability of Their Removal.

This examination showed that a considerable quantity of iron and acid were being discharged into the village sewers at the tube works. It was learned that these wastes were those produced in the operation of rinsing the tubes after pickling and that the copperas recovery plant suggested by the co-operative studies

of the State Board of Health and the United States Geological Survey had been in successful operation for some time so that the strong liquors no longer reached the Shelby sewage plant. Data obtained on this, the first detailed examination of this plant, indicated that the acid iron waste acts in large measure as a precipitant and consequently, the sewage contains a greater part of its organic impurities in a suspended state, and, therefore, readily lends itself to clarification by subsidence. The acid iron liquor soon loses its acid character, but converts the sewage into a weak solution of copperas and exhausts practically all the dissolved oxygen. From the point of entrance of the sewage into the plant until finally flowing from the filters, on this examination none of the crude nor purified liquors contained any dissolved oxygen. Moreover, the presence of iron interfered with bacterial action so that the organic matters in the sludge remained in a crude state, and as already related, were the cause of decided odors whenever it became necessary to clean the tanks and basins. The further effect of the presence of iron was the development of algal growths on the filters, and the speedy clogging of the filtering material. The effluent from the plant while low in organic matter and clear when discharged, soon became turbid in view of the oxidation of the iron which was initially present in the effluent in the ferrous state. Due to the presence of iron, the result of the discharge of the effluent was a marked discoloration of the creek. The iron further prevented nitrification in the filters and in general precluded the development of bacterial life.

Relation to Alkalinity of Sewage and Effluents. Samples for analysis were collected at half hourly intervals for the 24 hours covered by the test, and in the case of the crude sewage and the effluent from the sludge pits were divided into day and night periods, respectively. The remaining samples which comprised the effluent from the reservoirs and that from the filters were averages for the whole period of 24 hours. Alkalinity determinations were made on all these samples to determine the effect of the acid iron wastes upon the lime salts normally present in the sewage. Erythrosine was first used as the indicator, but in case the sample was acid to this indicator, phenolphthalein was employed. It will be noted by referring to the analytical results, that the day sewage and the day effluent from the sludge pits were both alkaline to erythrosine to the extent of 28 and 20 parts per million, respectively, expressed as calcium carbonate, but that during the night period these liquids were acid to this indicator. In the former case, the sewages showed phenolphthalein acidities of 43 and 152 parts per million, respectively.

The average of the effluent from the reservoirs which is the influent to the filters contained 3 parts per million alkalinity, as shown by erythrosine and 365 parts per million of acidity to phenolphthalein. The effluent from the plant was acid to erythrosine and showed a phenolphthalein acidity of 534 parts per million. In addition to these tests, the total iron was determined. The results are instructive as they indicate that the acidity is to be ascribed to iron salts and not to the presence of a free mineral acid.

These analytical data with reference to the alkalinity, the acidity and the iron present in the several sewages, as found on the first examination, are for convenience presented in the following table which also shows similar data obtained on the second examination, some four months after the acid iron wastes had been removed from the sewers.

TABLE NO. 41.

*Alkalinity and Iron in Sewages and Effluents on July 5-6, and November 14, 1906, Before and After Removal of Acid Iron Wastes.**

Source.	Parts Per Million.		
	Alkalinity.		
	Phenolphthalein.	Erythrosine.	Iron (Fe).
July 5-6, 1906—			
Crude sewage (day)	—43	28	240
Effluent sludge pits (day)	—152	20	160
Crude sewage (night)	—778	.....	420
Effluent sludge pits (night)	—773	.....	840
Influent filters	—365	3	180
Effluent filters	—534	.....	460
November 14, 1906—			
Crude sewage (day)	—227	175	62
Effluent sludge pits (day)	—432	133	162
Influent filters	—55	185	62
Effluent filters	—71	159	17

* Wastes removed August, 1906.

Removal Suggested. Acid iron wastes were withdrawn from the sewers in August, 1906. The State Board of Health then suggested to the tube works officials to arrange to neutralize the acid iron rinsing liquors before discharging them from the works. This recommendation was subsequently carried out. (See p. 767.)

Conditions After Removal of Acid Iron Wastes.

The next detailed examination was made after the iron liquors had been withdrawn from the sewers and after the plant had been extensively cleaned, as has already been stated. Although the acid iron wastes no longer reached the plant, yet it was noted that the red color was still in evidence on the surface of the reservoirs and that the filters were still more or less clogged with iron. It was found that the sewage still contained considerable iron, a feature due probably to the usually large quantity of iron in the ground water, and also to the fact that the iron removal plant, which treats the village water supply, was at that time not affording so complete a removal of iron as is desirable. Analytical evidence suggested interesting information as to the effect of the removal of the acid iron wastes. There was a marked decrease in the quantity of iron noted in the several sewages, but at this time there was practically no nitrification and only a limited quantity of dissolved oxygen in the final effluent. The results indicate that considerable iron was deposited in the reservoirs and on the filtering material and that conditions were yet such that oxygen introduced into the sewage would

immediately be absorbed and that the nitrification and destruction of the organic matter could not take place. The effluent from the plant, however, was non-putrescible and was substantially free from organic matter, but as previously found, on standing, rapidly deposited iron.

On the next examination, practically one year after the acid iron wastes had been removed, there was a decided improvement in the condition of the plant. Septic action was noted in the sludge pits and in the reservoirs, and the red film of iron was no longer noted on the surface of the sewage in the reservoirs and filters. At this time, however, the filters were greatly clogged and practically one-half of the sewage was being by-passed, a condition which suggested that the plant should be cleaned, as has already been discussed. On the final inspection of Oct. 14, 1907, the plant was found to be in excellent condition. It was very noticeable that the removal of iron from the sewage had greatly improved operating conditions and had allowed a satisfactory disposal of the sewage of the village even at the high actual rate of filtration which prevails at this plant. The appended detailed analytical data are instructive, as they show the tremendous effect of the acid iron wastes on the plant and as they illustrate the gradual decrease in iron, as suggestive of the cause for the greatly improved conditions which now obtain, results which have been brought about largely by suggestions made during this special investigation.

Clarification Afforded by Sludge Pits and Reservoirs.

The weakness of the Shelby crude sewage and the presence of iron have united to cause the sewage to be considerably coagulated and hence to allow of the somewhat rapid subsidence of the suspended matters. The average removals of suspended matter by the sludge pits and basins are shown in the following table.

TABLE No. 42.

Removal of Suspended Matter by Preparatory Devices.

Source.	Parts per Million Suspended Matter.			Percentage Removal.		
	July 5-6, 1906.	Nov. 14, 1906.	July 25, 1907.	July 5-6, 1906.	Nov. 14, 1906.	July 25, 1907.
Crude sewage (average)	136	163	42	.....	.....	.....
Effluent sludge pits	131	153	68	4	6	—62*
Influent filters	60	59	72	77	72	—71*

* Effect of clogged condition of plant.

SUMMARY.

Acid iron wastes from the tube works were first allowed to enter the sewers in the year 1902, when it was thought that the copperas would have a beneficial effect in coagulating the organic matters and thus render easier the purification of the sewage of the village. The quantity of iron and acid discharged, however, increased to such an extent that the iron eventually clogged the plant,

removed the dissolved oxygen from the weak village sewage, prevented bacterial action in the sludge and the nitrification of the organic matter by the filters. Finally it caused a marked discoloration of the creek by virtue of the iron contained in the effluent and was another source of pollution of the creek by iron in addition to that produced directly by the tube works. The result of this condition has been a number of suits which have been filed jointly against the village and the tube works. In June, 1906, however, a suit was filed against the village alone to restrain it from discharging sewage sludge into the Black Fork, as already stated. The cause of the alleged nuisance also appears to be directly attributable to the iron wastes which prevented the normal decomposition of the organic matters and caused the sludge to retain its putrescent character, so that when removed and exposed to the air it gave off foul odors and was a decided nuisance.

The practice of discharging sludge into the creek was at once stopped by the village and since that time has not been repeated. As suggested by the State Board of Health, the tube works were required to remove the acid rinsing liquors from the village sewers and as a result, the condition of the plant has slowly improved. At times, due to rapid clogging and to the fact that the cleaning of the plant had been postponed too long, some of the sewage has been by-passed without purification. The effluent from the plant has generally been low in organic matter, but has contained no dissolved oxygen, nor nitrates, but has been non-putrescible, presumably on account of the presence of a large quantity of iron, which apparently serves as a carrier of oxygen and renders the effluent ultimately stable.

After the removal of the acid iron wastes, sludge disposal has been carried out without nuisance from odors. In order to insure the treatment of all the sewage it is evident, however, from information obtained from this investigation, that the plant should be cleaned more frequently than twice a year. As noted on the final inspection, after a thorough cleaning in the summer of 1907, the plant was in good condition and the Black Fork was receiving practically no pollution from the sewage of the village and every effort was then made to prevent the discharge of polluting material into the stream. The officials of the village have been greatly interested in the plant and have heartily co-operated with the State Board of Health in this special investigation. The general results which have been brought out suggest that efforts should be made to reduce the flow of sewage during wet weather by eliminating down spout connections to the sanitary sewers. Furthermore, the plant should be visited more frequently, and if necessary the filters should be cleaned more often than has been true in order to prevent the clogging of the filters, so that the settled sewage will not be by-passed into the creek.

COSTS.

The first cost of the trunk sewer to the plant was $13,000. The cost of the plant alone was $6,500. The several items of cost are as follows:

Land and right of way	$2,500
Reservoirs	1,000
Tanks and filters	3,000
Trunk sewer	13,000
Total	$19,500

The operating expenses are chiefly those incidental to the cleaning of the

plant. The total operating expenses for the year 1906 were $750, which includes $96, the cost of cleaning the west reservoir, and $83, the cost of constructing the auxiliary sludge pit. Operating expenses for the year 1907 were $600. The costs of operation per person tributary for the above years are 47 cents and 37 cents, respectively.

TABLE NO. 43.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.																
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Alkalinity.	Dissolved Oxygen.	Putrescibility.	Fats.	Iron.	Phenol. Acid.
					Organic.		Free Ammonia.	Nitrites.	Nitrates.										
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.							
Crude Sewage.																			
July 5, 1906.....	7:00 A.-11:00 P.	....	40	37	10.4	4.8	5.0	0.04	0.0	22	164	51	....	28	0.0	....	6	240	43
July 5-6, 1906....	11:00 P.- 6:30 A.	....	154	86	5.8	4.9	4.0	0.01	0.0	25	81	30	....	.....	0.0	....	5	420	778
Weighted Av'ge.....		....	78	53	8.9	4.8	4.7	0.03	0.0	23	136	44	....	.....	0.0	....	6	300	288
Nov. 14, 1906....	8:00 A.- 8:00 P.	53	35	22	3.4	2.2	6.4	0.01	0.0	16	163	58	100	175	0.0	....	31	62	227
July 25, 1907.....	8:00 A.-10:30 P.	60	14	12	8.0	3.6	6.4	0.05	0.0	49	42	28	29	.....	0.3	....	76	4	...
July 25-26, 1907...	11.00 P.- 7:00 A.	56	10	9	5.6	2.4	4.0	0.07	0.0	27	41	29	23	.....	0.5	....	88	4.5	...
Weighted Av'ge.....		59	13	11	7.2	3.2	5.6	0.06	0.0	42	42	28	27	.....	0.4	....	80	4.2	...
Effluent Sludge Pits.																			
July 5, 1906.....	7:30 A.-11:30 P.	....	40	36	7.4	4.4	5.0	0.03	0.0	....	153	46	....	20	.....	....	5	160	152
July 5-6, 1906....	11:30 P.- 7:00 A.	....	89	82	6.8	3.3	5.0	0.01	0.0	....	88	54	....	.....	.....	....	5	840	773
Weighted Av'ge.....		....	56	51	7.2	4.0	5.0	0.03	0.0	....	131	49	....	20	.....	....	5	387	359
Nov. 14, 1906.....	8:00 A.- 8:00 P.	52	33	....	6.4	2.8	6.6	0.00	0.0	....	153	47	190	133	0.0	....	....	162	432
July 25-26, 1907..	8:00 A.- 8:00 A.	64	11	....	4.4	....	6.8	0.03	0.0	....	68	37	....	.....	.....	....	....	6.0	...

Effluent Reservoirs or Influent Filters.

July 5, 1906.....	7:30,A.- 7:00 A.	....	47	....	5.6	4.0	3.0	0.00	0.0	....	60	21	....	3	.....	....	....	180	365
Nov. 14, 1906.....	8:00,A.- 8:00 P.	43	7	....	2.8	0.8	6.2	0.00	0.0	....	59	....	24	185	1.2	....	....	62	55
July 25-26, 1907..	8:00 A.- 7.30 A.	69	11	....	3.9	....	5.3	0.00	0.0	....	72	43	....	.....	3.4	0	....	4.5	...

Effluent Filters.

July 5-6, 1906....	6:30 A.- 5:30 A.	....	54	....	1.3	....	6.6	0.00	0.0	....	90	36	....	.....	.....	....	....	460	534
Nov. 14, 1906....	8:00 A.- 8:00 P.	49	7	....	2.0	....	5.8	0.06	0.0	....	31	....	20	159	1.5	0	....	17	71
July 25-26, 1907..	8:00 A.- 7:30 A.	70	10	....	3.0	....	5.0	0.02	0.0	....	58	36	....	.....	2.5	0	....	10	...

XENIA.

The city of Xenia is in Greene County on the drainage area of the Little Miami River and directly on the south branch of Shawnee Creek which passes through the center of the city. According to local records the population is 10,000. Xenia is a manufacturing city. The most important industries are the manufacture of shoes, paper and machinery. A number of public improvements have been carried out up to the present time and they include a public water supply, improved streets, a system of sanitary sewers and a system of storm water drains. The public water supply was installed in 1887 and is derived from impounded spring and surface water, of which there is consumed daily 389,000 gallons, according to the records of the water company. Street improvements include about 4 miles of paving. Some sewers for sanitary use existed prior to 1900, but in that year they were considerably extended by the construction of a trunk sewer and three main branch sewers, 4 miles in length and built of vitrified pipe from 9 to 18 inches in size. The total length of the sanitary system is about 12 miles. The sanitary sewage of the city is conducted by gravity to one point where a sewage purification plant has been built. In addition to the sanitary sewers some storm water drains have been constructed, although for the greater part, the storm water is removed by natural water courses.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

Prior to 1900, some 1.2 miles of sewers existed in Xenia and while they were intended to be used only as storm drains, they received considerable domestic sewage which caused a very objectionable nuisance at the outfall in Shawnee Creek. Subsequently, plans were developed to provide a complete system of sanitary sewers and to prevent a continuance of the then existing nuisance in Shawnee Creek. These plans consequently embodied the purification of the sewage and a new outfall sewer which was carried some distance below the city proper.

The plans were presented to the State Board of Health and were finally approved in October 1901. The plans provided for purification by intermittent filtration preceded by partial sedimentation in shallow settling tanks.

EXAMINATIONS AND INSPECTIONS.

During this investigation, the plant was inspected on March 21, 1906 and March 12, 1907 and was examined in detail on August 16, 1906.

DESCRIPTION OF PLANT.

Briefly described, the plant comprises two settling tanks of brick and concrete, which average 11′-10″ x 25′ in plan and 4 feet to 4 feet 8 inches in depth. Each has a capacity of about 9,500 gallons. The inlet to each tank is a 15-inch pipe which is at the top of the tank. The outlets two in number are located in each corner of the end opposite the inlet and are 15-inch pipes the inverts of which are about 18 inches below the top of the tank. The tanks are covered with a flat hinged board roof.

The filters comprise four units, each 80 x 200 feet in area, or a total area of 64,000 square feet or 1.47 acre. They are composed of the natural gravelly sand on the site of the plant after stripping to a depth of 2 feet, surmounted with about 6 inches of bank sand found near the plant. The filters are underdrained at a depth of 2 feet 3 inches by a main drain of 10-inch vitrified sewer pipe which leads to an 18-inch outlet at the bank of Shawnee Creek and across

the Pennsylvania railroad tracks. Into the main drain enter 6-inch lateral drains 20 feet apart. No special means for distribution are provided, except shallow trenches in the filtering material.

Sewage flows to and from the plant by gravity and there is a decided fall from the village to the site of the plant. At the manhole a short distance above the plant, a by-pass is provided whereby the crude sewage may be caused to flow directly into the creek. The nearest house is about 660 feet distant.

SEWAGE FLOW AND CHARACTER OF CRUDE SEWAGE.

Gagings of the sewage flow were carried out for 12 hours on a partial detailed examination of this plant made on August 16, 1906. The average rate of sewage flow was 375,000 gallons in 24 hours.

As judged from the few available chemical data, the crude sewage is generally somewhat dilute and is essentially domestic in character.

OPERATION AND EFFICIENCY.

Except for short irregular periods, during this investigation, this plant has been out of service and the entire flow of crude, untreated, sewage has been allowed to discharge into Shawnee Creek. The city officials have been very indifferent to this condition and as a consequence, the decided pollution of the creek thus sustained, has continued in spite of efforts of the State Board of Health to improve existing conditions. The filters have been allowed to become overgrown with vegetation and are covered with sludge and in general the plant bespeaks the complete lack of the necessary supervision. The plant was in operation in the summer of 1906, and evidence is strong that the shallow settling basins, especially on account of the location of inlets and outlets are not efficient in the removal of suspended matter. The lack of efficient distribution is also clearly manifest as the sewage flows in narrow channels and covers only a small area.

Based on the sewage flow of 375,000 gallons in 24 hours the period of flow in the sludge pits is only about 0.6 hour and the linear velocity is 3.47 m. m. per second. When the filters operate, the approximate rate of filtration is 255,000 gallons per acre in 24 hours.

The poor condition of the plant is chiefly attributable to a lack of care and supervision. Recommendations for improvements, therefore, very properly emphasize the necessity for greater supervision and that there be at once discontinued the practice of allowing the crude sanitary sewage of the city to flow into Shawnee Creek without purification.

COSTS.

The first cost of the trunk sewer and the three main branches built in 1900 and that of the sewage purification plant are available only from the engineer's estimates which placed these respective costs at about $19,466 and $8,640, or in detail as follows:

Sewerage system, 4 miles		$19,466
Sewage purification plant, 66 acres of land at $40	$2,640	
Filters	3,000	
Incidentals	3,000	
Total		8,640
Grand total		$28,106

TABLE NO. 44.

Results of Chemical Analyses.

Date 1906.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.												
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Fats.
					Organic.		Free Ammonia.	Nitrites.	Nitrates.					
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.		
			Crude Sewage.											
Aug. 16.....	8:00 A.- 6:00 P.	74	28	.....	8.1	4.5	12.5	0.00	0.0	34	70	40	14.0	25
			Effluent Sedimentation Tank.											
Aug. 16.....	8:00 A.- 6:00 P.	74	23	.....	7.5	.....	11.5	0.00	0.0	34	50	23	7.6	....
			Effluent Filter.											
Aug. 16.....	9:00 A.- 6:00 P.	72	8	.....	5.4	.....	7.2	0.10	0.0	13	.....	.....	6.4	....

DELAWARE.

The city of Delaware is in Delaware County, on the Olentangy River, 24 miles from Columbus. The city is largely residential in character, is the seat of Ohio Wesleyan University and with the exception of the Big Four Railroad shops contains no large industrial plants. Public improvements were begun about the year 1889 when there was installed a public water supply obtained from a number of driven wells. According to the records of the water department, the daily consumption in 1906 was 545,000 gallons. A considerable part of the streets has been improved and the city now owns two miles of paved streets, containing 12,000 square yards of asphalt block and 30,500 square yards of brick pavement.

SEWERAGE.

A small inadequate system of sewers existed prior to 1902; these were primarily intended for the removal of storm water, but were also in part used for sanitary sewage. In 1902 there was built a complete system of sanitary sewers and as at present extended, the system comprises 12.5 miles of vitrified sewer pipe which ranges in size from 8 to 24 inches. According to the records of the engineering department, of the present population of 10,000, as exterpolated from the census reports, 4,000 or 40 per cent. are connected to the sewer system for sanitary purposes. In the fall of 1907, the total number of sanitary connections was about 600. As there are but few large industries in the city, the sewage is essentially domestic. The sanitary sewage flows by gravity to a point adjacent to the Olentangy River where it is subsequently purified. The sewers are intended to be strictly on the separate plan as the storm water is in the main removed by natural watercourses.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In planning a system of sanitary sewers for Delaware, it was recognized that local conditions would necessitate the purification of the sewage of the city, because its direct discharge into the Olentangy River would undoubtedly give rise to a local nuisance since the flow of the river at low stages would purify by dilution the sewage of only about 1,500 people. Accordingly, plans for sewage purification were prepared and were submitted to the State Board of Health for approval. The proposed plans were approved provided "that samples of purified sewage should be furnished the Board from time to time, as it might deem necessary, for examination, and if the sewage at any time was, in the opinion of the Board, insufficiently purified, the city of Delaware should cause to be made such changes of or additions to the purification plant as might be necessary to purify the sewage to a degree satisfactory to said Board." In the design of a purification plant an effort was first made to find soil suitable for irrigation or for intermittent filtration. It was found that no suitable land was available and that further a plant on this basis could not be operated unless the entire sewage flow should be pumped. Chemical precipitation works were not thought desirable owing to high cost of operation entailed. In view of the above, there was designed a purification plant comprising preliminary sedimentation in septic tanks followed by nitrification in coke contact filters. The plant was moreover located at such an elevation that the sewage of the city would flow by gravity to the point of disposal.

EXAMINATIONS AND INSPECTIONS.

During this investigation this plant was visited on Oct. 15, 1906; April 30, 1907, and May 8-9, 1907. This plant was not inspected until the fall of 1906, as

it was known that the plant was practically out of service owing to the failure of certain of the automatic devices by which it was intended to be operated. A visit, however, was made as stated with a view to recommending a means to placing the plant again on a proper operating basis. The question of reconstructing the plant was at that time taken up with the city engineer and the matter was seriously considered by the city officials. With a view to assisting the city in carrying out a proposed modification of the design of the plant, a detailed examination was made on May 8-9, 1907. This included the collection of samples and a gaging of the sewage flow for a period of 24 hours.

DESCRIPTION OF PLANT.

The plant as constructed is located on a tract of land, 12 acres in area, situated east of the Pennsylvania Railroad and south of the Big Four Railroad. The plant is completely isolated from the city and the nearest dwelling is a farm house about 1,600 feet distant. The plant as originally planned, was intended to provide a capacity of 250,000 gallons a day. It was assumed, however, that the plant could properly treat 400,000 gallons of sewage daily. Essential features of the plant are the automatic devices whereby the contact filters may be flooded and discharged automatically.

Screen and Grit Chamber.

The crude sewage reaches the plant through a 24-inch trunk sewer and is first screened by one-half inch iron rods spaced 6 inches in the clear and inclined 60 degrees to the vertical. The screen has an area of 28 square feet and is contained in a brick screen chamber 12x6 feet in plan and 6 feet deep. This chamber serves also as a grit chamber.

Septic Tanks.

After screening the sewage flows to the two septic tanks. These are constructed of brick and natural cement concrete with 8-inch end walls and 4-foot dividing walls, all of which are capped with 3-inch stone slabs. The dividing walls are built of one course of brick on each side with a center filling of natural cement concrete, hence the unusual thickness. The bottom of the tanks is of 6-inch concrete. One of the tanks is 15x50 feet in plan and the other 30x50 feet. The depth to the flow line ranges from 5 feet 6 inches to 6 feet 6 inches since the floor of the tanks slopes from the outlet to the inlet. The combined capacity of the two tanks is 100,000 gallons. The tanks are not covered.

Inlets and Outlets. Sewage from the grit chamber passes from the bottom of a main channel which extends the full length of the two tanks through 6-inch elbows, which are turned downward as they enter the tanks proper. The larger tank has two inlets and the smaller, one. The outlets are similar to the inlets and discharge into a similar outlet channel.

Baffles. The tanks are not baffled.

Sludge Drains. No drains are provided for the removal of sludge and it was originally intended to install a pump with special arrangements for removing sludge from the tanks. At present, however, no sludge disposal facilities are provided.

Method of Control. The rate of flow through the tanks is entirely dependent upon the quantity of sewage reaching the plant, although by plugging the inlets it is possible to operate one tank at a time only.

Aerating Channel. Sewage from the septic tanks flows directly on to the automatic flooding devices without provisions for aeration.

By-pass. The septic tanks are by-passed at times of high water by means of a float controlled flap valve which automatically shuts off the flow of sewage to

the plant and permits the direct flow of crude sewage to the river. The manhole containing this device is located inside the protecting levee which surrounds the entire plant.

Measuring Weirs. No means are provided for measuring the sewage flow.

Sludge Disposal Area.

As constructed, no provisions were made for a special area for the disposal of sludge. It was suggested, however, that land adjacent to the plant could be furrowed for the reception of sludge should it ever become necessary to clean the septic tanks. Pumping the sludge was contemplated in any event.

Contact Filters.

The purification of the septic effluent was intended to be carried out on coke contact filters, three in number, each with an effective area of 0.22 acre, or a total area of 0.66 acre. The filters are merely excavations in the natural clayey soil suitably underdrained. The filters are separated by earth embankments.

Filtering Material. The filtering material is fine coke approximately ½-inch in size and 3 feet in depth, surmounted by a 3-inch layer of gravel. In 1906, the original gravel layer had been removed.

Underdrains. Each filter is underdrained with a main 12-inch pipe into which lead three 6-inch lateral drains equally spaced. No lantern holes are provided and no special coarse material is placed directly over the underdrainage system.

Dosing Devices. The operation of the plant was intended to be automatically controlled at all times. To dose the filters, a dosing manhole is provided for the three filters in which is a special apparatus which consists of a three-way trough of galvanized iron supported on a ball and socket joint. This joint is an extension of the pipe which leads from the outlet channel of the septic tanks. The manhole itself is divided into three triangular compartments by concrete walls and in each compartment there is placed a galvanized iron float. The compartments are respectively cross connected to the three units with the expected result that as a filter is filling with sewage, the latter will rise in the dosing manhole to which it is connected by a 1½-inch pipe, and when full will force upward the galvanized iron float sufficiently to tip the three-way iron trough so that the discharge will be directed to the filter next in rotation. The manhole containing the dosing apparatus is provided with a 2-inch hinged wooden cover.

Distribution Devices. The main carrier to the dosing manhole is an 8-inch pipe. The discharge from the manhole takes place through a short length of pipe discharging flush with one side of a filter and at the surface of the filtering material. No special means are provided for distributing the sewage more thoroughly over the surface of the filters.

Effluent Discharge. Each filter when full is discharged when operated on the fill-and-draw plan, by a 3-inch siphon provided with a ⅜-inch air valve the opening of which is controlled by a lever arm and weight so arranged that the confined air may be released by the rise of a float. Each siphon chamber, similarly to the triangular compartments in the dosing manhole, is cross connected to the several filters, so that the sewage from the filter filling will cause a rise of the float in the siphon chamber and thus will permit the discharge of a unit which has been held in contact while the filter next in rotation is being filled.

The effluent from the contact filters is discharged through several hundred feet of 24-inch pipe to the Olentangy River. The plant is located on low land near the river at such an elevation that pumping is not obligatory. The outlet from the contact filters is, however, only about 0.5 foot above mean low water and hence only a slight rise in the river is sufficient to place the filters out of service.

To prevent the disastrous effect of floods, the entire plant is surrounded by a high dyke. To allow the septic tanks to be operated at such times when the contact filters can not be successfully used, a float controlled flap valve is placed in a special chamber into which discharges the outlet pipe from the filters. As a further precaution against floods, a similar flap valve is provided to by-pass the crude sewage as already described. It should be remarked, however, that the manhole for by-passing the crude sewage is located inside the protecting levee and with walls somewhat lower than the top of the levee so that the entire plant is flooded whenever the river rises sufficiently to overflow the top of the flap gate manhole, although the plant would be protected by the levee were the by-passing chamber situated outside instead of inside the embankment which surrounds the plant.

SEWAGE FLOW.

Estimates of the sewage flow at Delaware are available from data obtained on the detailed examination of the plant on May 8-9, 1907. As a result of these gagings which were continued at half-hourly intervals for 24 hours, it was found that the rate of sewage flow ranged from a minimum of 330,000 to a maximum of 519,000 and averaged 433,000 gallons in 24 hours. The quantity of sewage flow in the year 1903, according to the special report of the State Board of Health was estimated to range from 100,000 to 200,000 gallons, but since that date a number of new sewers have been constructed and there has been an increase in the number of connections to existing sewers. Although the sanitary sewers of the city are intended for sanitary use only, yet evidence available from this investigation shows that during wet weather the flow of sewage is very high. The fact that considerable ground water enters the sewers also no doubt, explains the high night flow which on May 9, 1907, was at the rate of about 330,000 gallons in 24 hours. The average flow found on May 8-9, 1907, corresponds to about 109 gallons per capita per person tributary. The water consumption based on the total population is about 55 gallons per capita, a fact which further indicates the large ground water factor at Delaware.

COMPOSITION OF CRUDE SEWAGE.

On the single detailed examination of this plant, samples of the crude sewage were collected at half-hourly intervals for 24 hours, beginning at 6:00 o'clock A. M. The method of sampling followed the general scheme already described. The day period was considered to be from 6:00 o'clock A. M. to 6:00 o'clock P. M. and the composite samples of the crude sewage representing the day and night flow, respectively, were mixed accordingly. The analyses of these composite samples indicated that the crude sewage was exceedingly dilute. The remarkably low suspended matter results, together with the presence of dissolved oxygen, nitrogen as nitrates and nitrites, severally indicate the tremendous influence of ground water and show that the sewage reaches the plant in a very fresh condition. Dissolved organic matter results further indicate that the sewage carries the greater part of its putrescible components in suspension. The analysis of the night sewage indicates that possibly at night the sewage could be directly discharged into the river without creating a nuisance from odors as no doubt a small dilution would suffice to prevent putrefaction.

Detailed results of the analyses of the crude sewage are appended to this report. It is of interest, however, to consider at this point the dilute character of the crude sewage as indicated by the dissolved oxygen results obtained on the examination of May 8-9, 1907, especially as the dissolved oxygen is not entirely destroyed in the passage of the sewage through the septic tanks. These data are shown in the following table:

TABLE NO. 45.

Dissolved Oxygen in the Crude Sewage and in the Effluent of the Septic Tanks on May 8-9, 1907.

Hour.	Temp. Deg. F.		Dissolved Oxygen. Parts Per Million.	
	Sew.	Eff.	Sew.	Eff.
8:00 A.	52	52	2.2	1.5
12:00 M.	52	52	0.8	0.4
4:00 P.	52	52	1.2	0.2
8:00 P.	52	52	0.4	0.0
12:00 Md.	52	52	1.1	0.0
4:00 A.	51	51	1.7	0.5
Average	52	52	1.2	0.4

OPERATION.

On the first inspection at Delaware made on October 15, 1906, it was found that very little attention had been paid to the plant and that the failure of the devices for the automatic operation of the contact filters had long since resulted in the abandonment of the fill-and-draw plan of operation. In its place, sewage from the septic tanks was allowed to flow without further treatment into the Olentangy River. It was learned that the city engineer had attempted to operate the contact filters as such by substituting hand operated wooden gates for diverting the sewage flow from one filter to the next. This expedient, however, did not prove successful, especially as the discharging apparatus was not operating normally. It was then attempted to operate the filters on a continuous basis, flooding them as just described, but it was found that the suspended matter in the effluent from the septic tanks soon formed a coating over the surface of the filtering material and prevented the passage of the effluent to the underdrains. This corresponded to an average rate of 655,000 gallons per acre in 24 hours or a population load of 6,000 persons per acre, or 2,000 per acre-foot. Attempts at even a rough purification of the sewage were then given up and the sewage of the city from that time until the end of this investigation has been allowed to flow into the Olentangy River following rough sedimentation in septic tanks holding about six hours' average flow.

EFFICIENCY.

From the above discussion, it is apparent that the Delaware sewage purification plant for some time past has not been in successful operation. While this is in part to be attributable to the largely increased sewage flow, yet it is primarily the failure of the automatic devices to which is to be ascribed the present poor condition of this plant. Neither the filling nor the discharging devices have been in successful operation for some time past, and the present sewage flow, moreover, is probably greater than could be carried by the piping of which the automatic devices is constructed.

On all visits to this plant its appearance showed that very little supervision

had been given to its operation. The septic tanks were about two-thirds full of sludge and as a result of the spring floods, which are said to have entirely inundated the plant, sludge was forced out of the tanks and when the waters receded quantities of sludge were deposited over a considerable part of the area within the protecting levees.

The condition of the plant was so poor and the lack of supervision so pronounced that the question of an improvement in existing conditions was taken up with the city engineer, as already stated. This official took an active interest in the matter and at once took steps looking to such changes and enlargements in the sewage plant as would insure a satisfactory purification of the Delaware sewage. During 1907 the question has been studied carefully by the Delaware officials and at the present time plans are on foot to change the Delaware plant to a sprinkling filter basis providing a pumping plant to afford the necessary head.

In considering what changes were necessary to improve conditions at Delaware, it was recognized that the capacity of the plant had long since been exceeded on account of the largely increased sewage flow and further that it would be more economical and practicable to change the design to that of sprinkling filters rather than to increase the number of contact filter units. This conclusion was reached especially in view of the fact that the present contact filters are at an elevation so low that a rise in the river of only 0.5 foot suffices to close the protecting flap valve and to necessitate the direct discharge of unpurified sewage.

Up to the fall of 1908, there have been no definite developments regarding a new sewage plant at Delaware. There is ample evidence to show the necessity for enlarging and reconstructing the present plant, and it is hoped that the proper disposal of the sewage of the city will be provided for without further delay.

SUMMARY.

Concluding this discussion of the sewage purification plant at Delaware it is to be stated that this plant is an example of those which have been greatly benefited by the special studies of the State Board of Health in view of the fact that interest has been awakened in the question of the disposal of the sewage of the city.

COSTS.

The cost of the present plant was $12,000.

The operating expenses have been practically nothing. During 1906, the plant received greater attention on the part of the engineering department of the city, but no extra expenses were incurred thereby.

TABLE NO. 46.

Results of Chemical Analyses.

Date 1907.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.												
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Dissolved Oxygen.	Fats.
					Organic.		Free Ammonia.	Nitrites.	Nitrates.					
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.		
			Crude Sewage.											
May 8.....	6:00 A.-10:00 P.	52	24	20	7.2	6.0	10.0	0.01	0.9	54	23	18	1.2	34
May 8-9.....	10:30 P.- 5:30 A.	52	18	16	2.4	1.6	5.6	0.20	2.0	49	27	18	1.4	12
Weighted Av'ge.....		52	22	19	5.6	4.5	8.9	0.07	0.7	52	24	18	1.3	27
		Effluent Septic Tanks.												
May 8-9.....	6:00 A.- 5:30 A.	52	25	.....	4.8	.....	11.2	0.00	0.0	51	37	26	0.4	.....

LAKEWOOD.

The village of Lakewood is on the shore of Lake Erie about five miles west of the city of Cleveland. It embraces an area of about six square miles, and according to local records, had a population in 1907 estimated at 10,000. The village is located upon a terrace which rises precipitously 60 feet at the lake shore and slopes from the top of the bluff southward, reaching a total elevation of 100 feet above the lake at the southern boundary of the village. The community is entirely residential and the village contains many large estates and handsome residences. Village improvements have advanced in keeping with the rapid increase in the population and at the present time practically all of the streets are paved, to the extent of 34 miles. A water supply was installed about the year 1900, when arrangements were made to obtain water from the Cleveland waterworks. The present consumption is in the vicinity of 725,000 gallons daily, according to the records of the Cleveland waterworks department.

SEWERAGE.

Elaborate plans for the sewering of the village were carried out in 1900, but since that date there have been a number of additions and enlargements made necessary by the ever-increasing population. At the end of 1907 the sanitary sewers comprised 34 miles of pipe sewers, which range in size from 8 to 24 inches. In addition to the sanitary sewers, there are some 20 miles of storm sewers, which range from 12-inch pipe sewers to 5-foot brick drains. All of the older sewers are underdrained and are on the separate system; the storm and sanitary sewers are laid in the same trench. Recent construction, however, has practically all been on the single system. To care for storm water in these cases there have been provided overflows leading to the lake.

With the exception of a narrow strip of land located on the lake front and situated at an elevation so low that sewage cannot flow into the main sewerage system without pumping, local topography allows the concentration of almost all of the sanitary sewage of the village at one point, namely, on low land near Rocky River village. In view of this condition, it is stated that considerable crude sewage discharges into the lake from residences on this small area on the lake front.

To provide for the purification of the sewage, a necessary feature of the sewering of Lakewood, as will be discussed later, the best plan was found to be the construction of a tunnel in the southerly part of the village, at the outlet of which the crude sewage is caused to enter an inverted siphon, which terminates at a sewage purification plant. This siphon is about 1165 feet long and is constructed of 10-inch iron pipe. A blow-off is provided at its low point. The working head is about 8 feet. To provide for the future growth of the village, in the river crossing, which was of masonry, there were laid two lengths of 16-inch iron pipe. At the inlet chamber, which leads to the siphon, the 10-inch pipe is blocked off by a brick wall to reduce eddies and to cause a clear entrance of sewage into the siphon. An intercepting wall is also placed in this chamber, containing three rows of 4-inch pipe placed nine inches on centers and surrounded by concrete. This arrangement practically serves as a screen to remove coarse material carelessly thrown into the sewer. A second line of sewers which, however, drain but a small part of the village, is caused to discharge at the site of the plant through a second inverted siphon.

Recent sewer construction (fall of 1907) contemplates connecting with the

Lakewood. — General View of One Contact Filter. Building, Housing, Dosing Apparatus in Center.

Lakewood. — Near View of One Contact Filter, Showing Distributing Troughs.

Cleveland sewers all of the Lakewood territory east of Cohassett street, embracing an area of 2.5 square miles and containing about 14 miles of sewers. This modification of the sewerage of the village will probably withdraw the sewage of about 5,000 persons. During this investigation it is estimated that 7,000 persons have been tributary to the sewers for sanitary purposes.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In discussing the sewering of the village, the matter was referred to the State Board of Health, which in 1899 adopted the following resolutions, namely, "That this Board is not willing to approve any plan of sewage disposal which contemplates the discharge of crude sewage into Lake Erie or the Cuyahoga River at any point within ten miles of the city's intake of drinking water." Subsequently, additional plans for the sewering of Lakewood were submitted to the Board, and as these plans did not prove satisfactory in view of the above resolutions, the Board advised the village that it would not approve of any plans for the sewerage of the village which contemplated the discharge of raw sewage into the lake even as a temporary measure, stating that it was the wish of the Board that plans for the purification of the sewage should be included in the sewering of the village. At the site of the plant, moreover, the sewage would be discharged into Rocky River, a stream of varying flow, having a watershed of 310 square miles. The dry weather flow is roughly estimated at from 4 to 6 cubic feet per second, and it is obvious that this small flow would by no means be sufficient to dispose of the Lakewood sewage by dilution, even if the protection of the purity of the water of Lake Erie were not given consideration.

In view of the above, plans for a system of sewerage and sewage purification were prepared and submitted to the Board in October, 1900. The plans were approved and the village was so notified in October, 1900.

The sewage purification plant as finally accepted by the State Board of Health and constructed in 1901, comprises essentially the treatment of the sewage in covered septic tanks, followed by aeration and final oxidation in cinder contact filters, operated automatically.

EXAMINATIONS AND INSPECTIONS.

Six visits were made to this plant and of these two were detailed examinations, which occurred on June 12-14, 1906, and June 12-13, 1907. Inspections only were made on April 10th and December 20th, 1906, and February 11th and October 17th, 1907.

DESCRIPTION OF PLANT.

The Lakewood sewage plant is on a 10-acre tract of land owned by the village and bordering on Rocky River at the extreme southerly part of the village. The site is well removed from dwellings and the nearest house, which is perhaps one-fourth of a mile distant, is situated on the bluff in the village proper, so that there are no houses in the immediate vicinity. The following description is supplemented by Plate XXX. and by Plates XXXI., XXXII. and XXXIII. (Mansfield).

Septic Tanks.

Aside from the rough screening the sewage may receive in the protecting chamber at the mouth of the inverted siphon, already described, and what small quantity of heavier mineral matters may be deposited in the siphon line, there are no provisions for screening and no tanks are set apart for the removal of the

sand and street washings. Discharged from both inverted siphons, the sewage flows into an inlet chamber 3x5 feet in plan and 7 feet deep, whence it enters the septic tanks proper. These are covered concrete tanks, two in number, each 36'-4"x74'-4" in plan and 11 feet deep. The low water flow line affords a depth of 9 feet 9 inches and the high water flow line gives an additional depth of 9 inches. The average capacity of each tank is 150,000 gallons and the total capacity is 300,000 gallons. The nominal period of flow, according to the original design, was 12 hours, when both tanks are in use.

The tanks are enclosed by a flat roof of concrete, reinforced by concrete arches on the lines of the piers. There are 15 brick piers in each tank 17 inches square in section and spaced 11 feet apart on both the longitudinal and sectional center lines of the arches. To offset the thrust on the lines of the arches, the walls are enlarged by buttresses opposite the center lines of the piers. The available head room between the maximum flow line and the roof is small and the tanks are accessible only through manholes. There are six manholes for each tank and they are symmetrically arranged. They are rectangular in plan and are 2 feet 3 inches square. The top of the roof is also covered with earth and is seeded. The arrangement of the manholes and the general features of the septic tanks are shown on Plate XXX. The design of the entire plant is similar to that at Mansfield. (See Plates XXXI., XXXII. and XXXIII.)

Inlets and Outlets. The sewage enters each tank through three 8-inch iron pipes, each 2 feet 9 inches below the lower flow line and spaced about one-third of the width of the tank apart. The main carrier from the inlet channel to the two tanks in turn is of 12-inch pipe, and one manhole is provided for each tank leading to the three 8-inch inlets. Flow through either manhole is controlled by an 8-inch valve.

Sewage discharges from the tank through two rows of 2-inch cast iron pipe, 12 inches on centers and 6 inches apart vertically between the rows of pipe. There are 66 pipes in each filter and the total available area is 1.44 square feet. These outlet pipes lead into a concrete channel 12 inches wide and 3 feet deep, in which are floating orifices, one of which controls the rate of discharge from each tank. This outlet construction is intended to insure a proportionate flow from all portions of the tank. As the outlet channel has a depth of 3 feet it is obvious that the outlets are trapped at all times.

Baffles. No baffles are provided.

Sludge Drains. Into the aerating channel which follows the septic tanks, there is a 12-inch drain controlled by a sluice gate, which allows the upper 6 feet of sewage in the tanks to be discharged onto the filters, leaving about 4 feet of sewage and sludge in the tanks. On this account should the removal of sludge become advisable it will be necessary to resort to pumping or the use of buckets.

Method of Control. The rate of flow from each septic tank is controlled by a specially designed floating orifice with an opening 2 inches wide and 12 inches long and a total area of 24 square inches. This orifice is arranged for adjustable submergence and is supported by two galvanized iron floats which are 2 feet 4 inches by 3 feet in plan and 8 inches deep. This device causes a constant quantity of sewage to flow from the septic tanks until the depth of sewage has fluctuated 9 inches or less, corresponding to the play of the float and the setting of the orifice with respect to the iron guides which support it. The floating orifices are located in the concrete channel adjacent to the septic tanks and in which terminate the 2-inch outlet pipes as already described.

By-pass. Crude sewage may be discharged directly into the river by opening a 12-inch sluice gate at the head of a 12-inch pipe which leads from the inlet chamber. It is also possible at this point to discharge the crude sewage directly to the filters. At the foot of the aerating channel, described below, there is pro-

vided a 12-inch gate, which allows the discharge of the septic sewage to the river.

At the mouth of the tunnel, that is at the head of the larger inverted siphon, there is an overflow to remove the excess of storm water. In case of clogging at the entrance to the siphon, crude sewage may be by-passed to the river without reaching the plant in case conditions at the mouth of the tunnel are not rigidly watched, as should always be the case after heavy rains.

Aerating Channel. From the floating orifices the sewage flows to an aerating chamber 5 feet wide and 13 feet long, designed to provide a total fall of 5 feet. It contains four steps 24 inches wide, each of which affords a drop of 15 inches. The sewage is discharged from the chamber by a 12-inch siphon, whence it falls into a collecting chamber 3 feet deep and 3 feet wide. In the bottom of this chamber valves are provided whereby the sewage may be discharged onto the filters or be by-passed as desired. At the foot of the aerating channel, just ahead of the collecting chamber, there is a wooden screen which extends the full width of the channel. It is constructed of 1½x¾-inch scantling, set at an angle of 45 degrees to the vertical, and with an open space of ¾ inch.

Measuring Weirs. No means were provided in the original design to measure the sewage flow, but during the greater part of this special investigation a temporary wooden weir has been installed about 4 feet below the discharge of the siphon in the aerating channel.

Sludge Disposal Area.

There are no provisions for the disposal of sludge, and as already mentioned the lower 4 feet of the tank can be drained only by combined pumping or shoveling, as conditions warrant.

Filters.

The septic sewage, after aeration, flows directly to the automatic dosing device, which operates the contact filters. These filters are five in number and are arranged as a circle with the dosing device in the center. Each unit consequently is a sector of a circle in shape. Each filter has an area of 0.125 acre and the total filter area is 0.625 acre. The five units are divided by earth embankments, which radiate from the central control house.

Filtering Material. The main body of the filtering material comprises 5 feet of cinders, which range in size from ¼ to 1½ inches, with an effective size of roughly 3.8 m.m. and a uniformity coefficient of 3.5. They were obtained from Cleveland and were delivered at the plant by rail. The cinders were prepared on the site of the plant by a special crusher and screen. To improve the appearance of the plant, a layer of coarse gravel was placed upon the cinders. At the present time (November, 1907), raking incidental to the operation of the plant has gradually intermixed the cinders and the gravel.

Underdrains. The filters are underdrained with a main drain which consists of 28 feet of 6-inch and 28 feet of 8-inch vitrified sewer pipe. The lateral drains are 4, 6 and 8 inches respectively. In general, the tile are laid 20 feet apart. There are no lantern holes nor other means for ventilating the underdrains. The entire bottom of the filter is covered to a depth of 3 inches with coarse cinders, which have a depth over the tile of 1 foot 3 inches. The upper surface of the underdrains it at the level of the bottom of the filter so that ordinarily the filter is drained completely. Similarly to Mansfield, provisions are made so that the underdrains can be back flooded and remain full at all times if found desirable.

Automatic Dosing and Discharging Apparatus. The dosing and discharging apparatus at this plant is similar to that at Mansfield, and as the latter

antedates the Lakewood plant, the machine will be fully described in the description of the Mansfield plant. (See p. 513.)

Distribution Devices. The discharge from the dosing chamber is carried through about 15-foot lengths of 12-inch iron pipe, which terminates in a concrete culvert. The surface distribution is effected by a branched wooden carrier 6 inches deep with width in the case of the main distributor, which ranges from 24 inches to 6 inches. The lateral lines are 12 inches and 6 inches in width, respectively. One lateral line is provided at each side of the main distributor, and is 35 feet from the apex of the filter. At each change of section, hinged gates allow the diversion of a greater or less volume of sewage. At these points also there are provided wooden discharging slabs to prevent undue disturbance of the gravel. These slabs are 2 feet 6 inches by 4 feet in plan.

Effluent Discharge. The effluent from the contact filters enters a back flooding chamber, as does also the pipe from the toe of the aerating chamber. This chamber provides a means for protecting the filters during floods. The highest known flood at the site of the plant is at elevation 9, the surface of the filters is at elevation 16.5, and the bottom of the filters is at elevation 10. The effluent from the contact filters flows to the Rocky River through 216 feet of 15-inch pipe, which terminates at a concrete culvert on the bank of the stream.

Sewage Flow.

Since June, 1906, daily records have been kept at this plant of the quantity of sewage flow. The weir readings have comprised one daily measurement made at a different hour each day of the week. From these measurements there has been obtained approximately the range of the volume of sewage flow. These data are presented in Table No. 47, which shows the quantity of sewage by months for a considerable part of this investigation. The average daily flows by months have ranged from 372,000 to 1,045,000 gallons. This wide range in the sewage flow indicates the tremendous influence of ground and storm water on the sanitary sewage of Lakewood. The volume of sewage has been so great that at times it is necessary to open the by-pass and discharge the sewage into Rocky River. The average flow in dry weather is about 500,000 gallons in 24 hours and corresponds to about 72 gallons per person tributary. The flow of strictly domestic sewage will no doubt be greatly diminished in the spring of 1908, when connection is made to the Cleveland sewers of the densely populated area east of Cohassett street.

TABLE NO. 47.

Sewage Flow by Months.

Month — 1906-07.	Gallons in 24 Hours.		
	Maximum.	Minimum.	Average.
June, 1906	393,000	267,000	372,000
July	1,290,000	287,000	400,000
August	3,540,000	267,000	568,000
September	968,000	247,000	390,000
October	2,280,000	105,000	738,000
November	1,940,000	665,000	838,000
December	1,535,000	445,000	833,000
January, 1907	1,520,000	595,000	1,045,000
February	1,879,000	570,000	746,000

TABLE NO. 47 — Concluded.

Month — 1907.	Gallons in 24 Hours.		
	Maximum.	Minimum.	Average.
March	1,045,000	595,000	811,000
April	1,030,000	621,000	834,000
May	1,535,000	676,000	923,000
June	1,535.000	845,000	1,012,000
July	1,360,000	595,000	668,000
August	915,000	545,000	665,000
September	880,000	545,000	700,000
October	1,680,000	600,000	910,000
November	1,030,000	600,000	650,000
December	1,980,000	620,000	970,000

On the detailed examinations, records of the sewage flow were noted, in all cases, at the outlet of the septic tanks. The rate of flow from the septic tanks is constant, except when the quantity of sewage increases sufficiently to cause an overflow over the crest of the orifice plates and consequently it is not possible to determine hourly variations in the flow of the crude sewage. The two examinations, made practically a year apart, indicated an average flow of sewage of 395,000 and 1,150,000 gallons in 24 hours, corresponding to 56 and 164 gallons per person tributary. On the second examination large volumes of ground water were flowing into the sanitary sewers.

COMPOSITION OF CRUDE SEWAGE.

For reasons just stated it is impracticable to obtain an average sample of the crude sewage weighted in proportion to the sewage flow. Samples of the crude sewage were, therefore, collected at the inlet chamber of the septic tanks and were mixed in equal portions to correspond to the flow through the inverted siphon for a period of 24 hours. Two analyses of the crude sewage thus collected are available from the results of this investigation. These afford ample evidence that the Lakewood sewage is very dilute. Of special significance in this regard is the nitrogen content, the low oxygen consumed and the constant presence of dissolved oxygen. The high per capita sewage flow and the entrance of ground and storm water into the sewers naturally accounts for the especially weak character of the crude sewage. The oxygenation is well illustrated by the results obtained on the detailed examination of June 12-13, 1907, and presented in the following table.

TABLE NO. 48.

Dissolved Oxygen in Crude Lakewood Sewage.

Hour — June 12-13, 1907.	Parts per Million Dissolved Oxygen.
8:00 A. M.	6.1
12:00 Noon	6.0
4:00 P. M.	5.6
8:00 P. M.	5.3
12:00 Md.	2.2
4:00 A. M.	5.7

The analyses on the second examination illustrate that the Lakewood sewage carries a considerable quantity of inorganic suspended matter, as only about 35 per cent. of the material in suspension was volatile. Details of the character of the crude sewage, as found on the two detailed examinations, are appended. It is to be noted also that at times of storms the sewage is still more highly dilute than these figures indicate.

OPERATION.

This plant is operated by the village sewer inspector, who devotes a part of his time to this work. At times he is assisted by one laborer, who is employed for perhaps one day per week. The plant is practically automatic, no pumping is necessary; the labor involved in its operation is merely the attention necessary to maintain the automatic apparatus in proper condition and the occasional raking and cleaning of the surfaces of the contact filters. During this investigation, excellent records have been kept of the sewage flow, temperature, etc. Putrescibility tests have been faithfully performed each day.

Inverted Siphon.

After heavy storms it is customary to inspect the inlet of the inverted siphon, especially to clean the screen, which at times has been found clogged with coarse matters carried by the sewage during storms. The siphon has been in entirely successful operation since it was constructed. In the spring of 1907, as a precautionary measure, the blow-off was opened and the siphon was cleaned out. A considerable quantity of finely divided sludge was removed.

Septic Tanks.

Throughout this investigation, both septic tanks have been in service. Occasionally the sewage flow has been so great that it has exceeded the capacity of the floating orifices and sewage has flowed over the top of the orifice plate. (Examination of June, 1907). At times also on account of an exceedingly high flow of sewage the effluent from the septic tanks has been caused to flow directly into Rocky River. According to the records kept at the plant, this step was necessary on two days in 1906 and 11 times in 1907, a total period of 24 days. No sludge has been removed from the septic tanks since they were first placed in operation, and no difficulties have been experienced due to the clogging of the

outlets. Based on the average sewage flow, the period of flow is about 12.4 hours and the linear velocity is 0.50 m.m. per second. Sludge accumulation, however, has probably reduced the period about 35 per cent. and has correspondingly increased the linear velocity. *

Contact Filters.

During the summer months four contact filters are in use, and one is rested for a period of one week by means of the two-fifths segment gear. During cold weather, however, it is stated that the gears do not mesh accurately, tend to bind and stop the mechanism and consequently at the advent of cold weather, the segment gear is removed and all five of the filters are in service. Ordinarily, the plant is operated strictly on the fill-and-draw basis, that is, one filter is receiving sewage, one is held full and another is drained. The automatic apparatus which, of course, requires the cleaning and oiling necessary for all machinery, generally speaking, has been entirely successful. At times sand carried by the sewage of Lakewood during wet weather has found its way between the fixed and movable cylinders, has partially stopped the movement of the mechanism and has prevented the proper function of the machinery.

No material has been removed from the contact filters since they were first placed in service. During this investigation the filters were cleaned and raked on five occasions, as follows: In 1906, August 3 days, November 4 days; in 1907, April 6 days, July 5 days and August 1 day. The plant is visited once daily by the sewer inspector, who supervises the operation of the automatic devices. For putrescibility, chemical and smell tests have been carried out with considerable success. The supervision of this plant is excellent and its general appearance is deserving of special commendatory mention.

On June 12-13, 1907, for a period of 24 hours, the four filters in service were flooded three times each. Based on the average sewage flow of dry weather with one filter out of service, the rate of filtration has averaged 800,000 gallons per acre in 24 hours. Under wet weather conditions, as indicated by the range in the volume of sewage flow, the contact filters have been operated at rates per acre in 24 hours at times as high as 2,500,000 gallons. During the winter the rates are, of course, 20 per cent. lower than the above, as all five filters are in use daily. The population load is 11,200 persons per acre and 2240 persons per acre-foot. The successful maintenance of this heavy population load is, no doubt, in part due to the fact that a large part of the male population are in Cleveland during 10 to 12 hours each week day.

EFFICIENCY.

The degree of purification effected by the Lakewood sewage purification plant has been learned by the detailed examinations, by the several visits of inspections and by daily records and putrescibility tests.

Septic Tanks.

Information obtained during this investigation has shown that the septic tanks at Lakewood have been operated without odor, and that they have been generally successful as preparatory treatment for the Lakewood sewage. The sewage is so dilute that no permanent scum is formed on the surface of the sewage in the septic tanks. The influence of storm water on the crude Lakewood sewage, and especially the presence of mineral matter, has had a marked effect, however, on the capacity of the septic tanks. Measurements of the sludge have shown a gradually increasing deposit and on the detailed examination of June

* Sludge was removed from the septic tanks, Aug. 23 to Sept. 24, '08.

12-13, 1907, it is estimated that the volume of sludge in the two tanks was about 634 cubic yards, or 32 per cent. of the capacity of the tanks. The deposition of sludge is especially interesting. At the inlet end of the tanks nearest the discharge of the inverted siphon the sludge was 5 feet in depth and was very hard and compact, suggesting that it contained considerable mineral matter. The depth of sludge in the west tank ranged from 59 inches at the inlet to from 29 to 30 inches at the outlet. In the east tank the inlet end contained from 36 to 41 inches of sludge and the outlet end 30 inches. This condition suggests that in the near future it will be necessary to clean the tanks.

It is of special interest to note that there has been very little evidence of excessive fermentation in the sludge. Fermentation is, of course, very active in the summer months, and from information available it appears that in hot weather considerable suspended matter is carried out of the tank with the septic effluent. The analytical evidence on this point was obtained on the detailed examination in 1907 and indicated that the removal of suspended matters by the septic tanks was then negative, as the septic tank effluent contained 138 parts per million of suspended matter as against 101 parts in the crude sewage. The septic effluent as discharged is generally black in color, but has very little odor. The successful operation of the septic tanks without cleaning and the fact that these non-baffled tanks have been operated without serious detriment to the contact filters by virtue of a discharge of high suspended matters, is possibly to be attributed largely to the dilute character of the Lakewood sewage. On each of the detailed examinations it has been found that the effluent from the septic tanks, even before passing the aerators, is well aerated. On June 13, 1907, samples of the septic effluent before aeration were found to contain 4.5 parts per million of dissolved oxygen and after aeration 5.9, 4.5 and 5.0 parts per million, respectively.

As before stated, at times the high rate of sewage flow causes the floating orifices to rise to the limit, until finally sewage passes over the top of the iron crest. The galvanized iron floats appear to be in good condition and they have not as yet deteriorated, as was found at Mansfield. A careful examination of the outlet channel of the septic tanks was made to learn if the accumulation of sludge at that point was sufficient to cause a stoppage in the series of 2-inch iron pipe which serves as outlets. It was found that there was a very finely divided deposit which was from 3 to 4 inches in depth and apparently did not interfere with the free flow of sewage through the outlets. The depth of sludge in the septic tanks at the outlet ends at this time (June 12-13, 1907) was only about 2½ feet, and hence there is no obstruction of the outlets from the inside of the tank. It is interesting to compare these conditions with those at Mansfield, where a frequent cleaning of the outlet channel is necessary.

Contact Filters.

The putrescibility tests have for the greater part served to indicate the general efficiency of the final step of the purification of the Lakewood sewage. These daily tests have, of course, been supplemented by analytical evidence obtained on the two detailed examinations. All of the information available indicates that the dilute sewage of the village is thoroughly purified by the contact filters to a state of ultimate stability. The analytical evidence appended shows the results obtained from individual filters on the detailed examination of June 12-13, 1907. It will be noted that there was very little difference in the work of the four filters then in service. Their effluents were normal for contact filters, were low in suspended and organic matters, were non-putrescible and contained considerable nitrified nitrogen.

Certain information as to the average condition of the Lakewood effluent, as shown by the daily putrescibility tests, is listed in Table No. 49.

TABLE NO. 49.

Monthly Records of Daily Putrescibility Tests.

Month — 1906-07.	Odor.			Chemical Test.		
		Percentage.			Percentage.	
	Total Tests.	Positive.	Negative.	Total Tests.	Positive.	Negative.
June, 1906	17	0	100	6	17	83
July	31	0	100	31	3	97
August	31	3	97	31	3	97
September	30	0	100	30	3	97
October	31	0	100	31	3	97
November	30	0	100	30	3	97
December	31	0	100	31	3	97
January, 1907	31	0	100	31	0	100
February	28	0	100	28	0	100
March	30	0	100	30	3	97
April	30	0	100	30	0	100
May	30	0	100	30	3	97
June	30	0	100	30	3	97
July	30	0	100	30	3	97
August	27	0	100	27	3	97
September	30	0	100	30	3	97
October	27	0	100	27	4	96
November	28	0	100	28	7	93
December	24	0	100	24	0	100

Of considerable importance in reviewing the efficiency of the Lakewood contact filters is the question of the clogging and the reduced capacity from years of service. On each of the detailed examinations a careful record was kept of the operation of the filters with respect to the period of filling, standing full and draining. From these data in connection with the practically constant flow of sewage from the septic tanks it is possible to obtain a rough knowledge of the quantity of sewage required to fill the pores of the contact filters to the point at which the sewage would be automatically diverted to another unit. Data obtained on the examination of 1906 would be interesting for the sake of comparison with those obtained in 1907, but unfortunately this information is not considered reliable, as for some reason, possibly due to clogging in the automatic apparatus, the filters required from 7 to 8 hours to fill under a normal sewage flow and hence the capacities of the filters were unreasonably high. The 1907 data, however, are listed below and indicate that the average percentage of voids is 35.6 and that the voids in the five filters ranged from 32.9 to 38.0 per cent., figures which approximate the generally assumed average per cent. of voids for cinder filters. According to the above figures the average dose is 74,000 gallons. It will be of interest also to record certain data concerning the automatic operation of the contact filters in June, 1907. At this time filter No. 3 was out of service. The length of cycles, of course, depends upon the sewage flow and that of the night hours is, of course, low and the periods are protracted.

TABLE NO. 50.

Operation of Contact Filters, June 12-13, 1907.

Filter No.	Details of Operation.			Length of Cycles—Hours.			
	Began to Fill.	Full.	Began to Discharge.	Filling.	Standing Full.	Draining.	Resting.
1	8:20 A. M.	10:15 A. M.	11:52 A. M.....	1.92	1.62	1.63	1.75
2	10:15 A. M.	11:52 A. M.	1:30 P. M.....	1.62	1.63	1.75	1.60
4	11:52 A. M.	1:30 P. M.	3:15 P. M.....	1.63	1.75	1.60	1.87
5	1:30 P. M.	3:15 P. M.	4:51 P. M.....	1.75	1.60	1.87	1.80
1	3:15 P. M.	4:51 P. M.	6:43 P. M.....	1.60	1.87	1.80	1.68
2	4:51 P. M.	6:43 P. M.	8:31 P. M.....	1.87	1.80	1.68	7.47
4	6:43 P. M.	8:31 P. M.	10:12 P. M.....	1.80	1.68	7.47	1.67
5	8:31 P. M.	10:12 P. M.	5:40 A. M.....	1.68	7.47	1.67	1.58
1	10:12 P. M.	5:40 A. M.	7:20 A. M.....	7.47	1.67	1.58	1.48
2	5:40 A. M.	7:20 A. M.	8:55 A. M.....	1.67	1.58	1.48	1.30
4	7:20 A. M.	8:55 A. M.	10:24 A. M.....	1.58	1.48	1.30	1.65
5	8:55 A. M.	10:24 A. M.	11:42 A. M.....	1.48	1.30	1.65	1.48
1	10:24 A. M.	11:42 A. M.	1:21 P. M.....	1.30	1.65	1.48	1.50
2	11:42 A. M.	1:21 P. M.	2:50 P. M.....	1.65	1.48	1.50	1.40
4	1:21 P. M.	2:50 P. M.	4:20 P. M.....	1.48	1.50	1.40	1.75
5	2:50 P. M.	4:20 P. M.	5:44 P. M.....	1.50	1.40	1.75	.....
1	4:20 P. M.	5:44 P. M.	7:29 P. M.....	1.40	1.75	.....	.....

Ordinarily sewage never rises above a point six inches above the surface of the filtering material. At times, especially when very large quantities of suspended matters are discharged from the septic tanks, sludge deposits are formed near the distributors on the contact filters. Under the excellent management, however, these deposits are not allowed to accumulate, and in general the surface of the contact filters is free from clogging, and as found by an inspection of the material there has been no disintegration and very little settlement. After about five years of service the wooden distributors have begun to decay and now need renewal. The general appearance of the contact filters is excellent, the grounds are well kept, the grass is cut and the walks are kept in excellent condition. No special difficulties have been experienced because of high water in Rocky River. The plant has been by-passed, as already stated, in view of high waters, but the water has not risen sufficiently to injure the contact filters nor the automatic apparatus.

SUMMARY.

The results of this investigation show that the sewage of the village of Lakewood is purified by this plant to a very satisfactory degree. There is practically no odor about the plant even in warm, muggy weather of summer, and no difficulties have been experienced in operation under extreme winter conditions. The dilute character of the crude sewage no doubt in part explains the successful operation of the septic tanks, which up to the close of this investigation have not been cleaned. The tanks have, however, accumulated considerable sludge, in a large part presumably in view of the entrance of storm water into the Lakewood sewers, and it is probable that the tanks will require cleaning in the spring of 1908. The normal sewage flow has been treated at the plant without difficulty and sewage has been discharged into the river directly only when necessary on account

of a large increase in the flow of sewage due to storms. While the plant is essentially automatic in its operation, yet the intelligent supervision it has received, the continued successful operation of the automatic devices and its general appearance, illustrate the great advantage which accrues from proper supervision even when the operation of a plant is to be classed as strictly automatic. While the ordinary dry weather flow of the village during this investigation has been handled without difficulty, yet a large increase in the flow would undoubtedly make necessary the construction of additional septic tanks and contact filters as provided for in the original design. It is the case, however, that the sewage of about 5000 people, or specifically from the population of Lakewood east of Cohassett street, will be caused to flow directly into the new intercepting sewer of the city of Cleveland and in the spring of 1908 the volume of domestic sewage reaching the plant will be considerably reduced. In view of these conditions it is probable that the Lakewood plant as it now exists will have ample capacity for several years in the future. Recent sewer construction has tended towards enlarging the sanitary sewers in certain districts where they have been carrying both storm water and sanitary sewage, and as soon as these changes are made they will tend to improve conditions at the Lakewood sewage purification plant, which at times is seriously effected by the large volume of storm water which reaches the sanitary sewers.

COSTS.

The original estimate of cost for sewers and for the sewage purification plant was $145,110, of which amount the purification plant, including the septic tanks, contact filters and land, was $26,675. The several estimates of first cost for this plant, including the cost of the original sewers, is as follows:

Septic tanks	$6,775
Five-eighths acre contact filters	17,400
Land	2,500
Lateral sewers	53,000
Intercepting sewers	54,700
Inverted siphon	10,735
Total	$145,110

The cost of operation of this plant is small. There are no expenses for pumping and the daily operating costs comprise the time of the sewer inspector, which averages one hour per day at an estimated cost per year of $125. In addition to this item, a laborer is employed one day per week at $1.85 per day. In 1906, extra labor was employed only from March 15th to November 15th. Several items listed as supplies and repairs and a small item of labor increases the annual cost to $221 and $284 for the years 1906 and 1907, respectively, or 3 cents and 4 cents per capita per annum for the above two years. Details of the cost of operation of this plant are listed in the following table.

TABLE NO. 51.

Cost of Operation for the Years 1906 and 1907.

	1906.	1907.
Salaries	$125 00	$125 00
Supplies and repairs	35 00	55 00
Extra labor	61 00	104 00
	$221 00	$284 00

TABLE NO. 52.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.													
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.
					Organic.		Free Ammonia.	Nitrites.	Nitrates.							
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.				
Crude Sewage.																
June 12-13, 1906..	12:00 P.-11:30 P.	53	24	18	3.4	1.0	10.0	0.02	0.2	59	46	39	10	1.2	....	31
June 12, 1907.....	8:00 A.-11:30 P.	53	14	12	3.0	1.0	5.0	0.24	1.1	39	111	37	33	5.8	....	29
June 12-13, 1907..	12:00 P.- 7:30 A.	53	10	9	2.8	1.0	2:0	0.18	0.2	30	80	32	21	3.9	....	15
Weighted Av'ge.		53	13	11	2.9	1.0	4.0	0.22	0.8	36	101	35	29	5.2	....	24
Effluent Septic Tanks (Influent Contact Filters.)																
June 13, 1906.....	No. 1,10:20 A.- 2:30 P.	54	14	.....	4.4	2.4	10.2	0.10	0.2	.....	40	36	....	.....	....	...
June 13, 1906.....	No. 3, 2:30 P.-10:30 P.	54	15	.....	14.4	4.4	12.8	0.00	0.0	.....	39	37	....	.....	....	...
June 13-14, 1906..	No. 4, 10:30 P.- 7:30 A.	54	14	.....	3.6	.....	11.2	0.00	0.0	.....	37	30	....	.....	....	...
June 14, 1906.....	No. 5, 7:30 A.- 3:40 P.	53	16	.....	13.8	4.2	12.0	0.01	0.0	.....	58	32	....	.....	....	...
June 13-14, 1907..	8:00 P.- 7:30 P.	54	15	.....	6.0	.....	4.4	0.22	0.0	.....	138	42	....	5.2	....	...
Effluent Contact Filters.																
June 13-14, 1906..	No. 1, 10:27 P.-12:27 A.	54	6.0	.....	0.5	.....	4.4	0.04	0.0	.....	5	.....	....	2.9	0	...
June 14, 1906.....	No. 3, 7:45 A.- 9:45 A.	55	5.0	.....	0.8	.....	6.4	0.05	0.3	.....	3	.....	....	3.0	0	...
June 14, 1906.....	3:40 P.- 5:40 P.	54	5.0	.....	0.3	.....	5.6	0.01	0.0	.....	8	.....	....	2.4	0	...

June 14, 1906.....	No. 5, 5:40 P.- 7:40 P.	54	4.0	.....	2.5	.....	2.4	0.03	0.0	.....	3	.....	....	.....	0	...
	No. 3, 8:31 P.-10:12 P.															
	8:55 A.-10:24 A.															
June 13-14, 1907..	2:50 P.- 4:20 P.	54	4.6	.....	0.9	.....	1.5	0.11	0.2	.....	37	27	....	3.9	0	...
	No. 4, 10:12 P.- 5:40 A.															
	10:24 A.-12.42 P.															
June 13-14, 1907..	4:20 P.- 5:44 P.	54	5.0	.....	1.3	.....	1.3	0.08	2.2	.....	58	15	....	3.9	0	...
	No. 5, 5:40 A.- 7:20 A.															
	12:42 P.- 1:21 P.															
June 13-14, 1907..	5:44 P.- 7:29 P.	54	7.0	.....	0.9	.....	1.1	0.12	4.0	.....	44	28	....	3.9	0	...
	No. 1, 7:20 A.- 8:55 A.															
June 13-14, 1907..	12:11 P.- 2:50 P.	54	4.9	.....	1.2	.....	1.4	0.11	2.0	.....	32	22	....	3.9	0	...

LONDON.

The village of London is in the central portion of Madison County upon Oak Run, a small branch of Deer Creek, tributary to the Scioto River. According to local records, the village has a present population of about 4,000. The total area within the corporation limits is 1,445 acres and of this area about 800 acres have been divided into streets. None of the streets have been improved and public improvements have been few save a public water supply which was installed in 1889. The source of the supply is driven wells, from which the daily consumption in 1906 was 275,000 gallons according to the records of the water department. The village is devoted almost exclusively to agricultural pursuits and is an extensive cattle market.

SEWERAGE.

The question of a system of sanitary sewerage for the village was first agitated about the year 1900, when serious nuisance was experienced due to the discharge of crude sewage into an open ditch near the built-up portion of the village. This nuisance led to an investigation by the State Board of Health, and as a result, the Board strongly advised the construction of a complete system of sanitary sewers. Several years later, plans for a sewer system were prepared and in 1907 the first sanitary sewers were constructed. The system comprises 7 miles of pipe sewers, which range in size from 8 to 18 inches. The sewers are subdrained throughout with from 4 to 10-inch drains. The new sanitary sewer system contains 19 flush tanks and 73 manholes, which are from 8 to 24 feet deep. The sanitary sewage is conducted by gravity to a purification plant located just beyond the corporation limits. In November, 1907, only about 500 people were estimated to be tributary to the sanitary sewers.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In preparing plans for a system of sanitary sewers, it was recognized that local conditions would demand the purification of the sewage, since the only available means of its disposal by dilution was Oak Run, which has a dry weather flow of only from 1 to 3 cubic feet per second and would, of course, be grossly polluted by the sanitary wastes of 4,000 persons. Accordingly, plans for a system of sanitary sewers included also the purification of the resulting sewage. These plans were submitted to the State Board of Health and were approved in April, 1904. As presented, these plans provided for the collection of the crude sewage in an 18-inch trunk sewer, through which it was to be conducted to the purification plant located some 1,500 feet southeasterly from the corporation limits and between Oak Run and Main Street. The proposed purification plant in general terms provides sedimentation in septic tanks, followed by treatment on single contact filters, which were to be operated by automatic filling and discharging devices.

EXAMINATIONS AND INSPECTIONS.

This plant was not finished until the summer of 1907, and at the end of this investigation only a small volume of sewage was receiving treatment. In its constructional stages it was inspected on October 9, 1906, and again on November 6, 1907, after construction was completed and a small volume of sewage had begun to flow to the plant.

DESCRIPTION OF PLANT.

The London sewage plant is located on 4.62 acres of land bordering on Oak Run, a short distance beyond the corporate limits of the village.

Grit Chamber.

The crude sewage without screening flows into a concrete grit chamber of about 3,500 gallons capacity, hexazonal in plan, 7 feet wide, 15 feet 6 inches long and 5 feet 6 inches deep. The tank is divided by a concrete dividing wall 6 feet long, 18 inches high and 6 inches thick, forming two 3-foot channels. The 18-inch sewer enters this chamber with its invert 2 feet above the bottom. Flow through the two compartments is controlled by stop planks which allow one or both sides of the chamber to be used as desired. The chamber is covered with a 2-inch plank cover hinged in the center.

Septic Tanks.

Passing from the grit chamber through about 8 feet of 18-inch pipe, the crude sewage flows into two uncovered septic tanks. These are of concrete with 24 inches side walls and 3-foot 6-inch center walls and 12-inch base. Each tank is 30 feet x 8 feet 7 inches in plan and 10 feet deep and to the flow line 9 feet deep, and of 17,350 gallons capacity.

Inlets and Outlets. The inlet to the tanks is a channel 18 inches wide extending the entire width of the tanks. Located 6 feet 6 inches from the ends of the tanks, and 4 feet apart, two 6-inch elbow inlets are provided flush with the bottom of the inlet channel and turned down to enter the tanks with their inverts 3 feet 3 inches below the flow line.

The outlets are similar and are located in a similar outlet channel.

Baffles. The tanks are not baffled.

Sludge Drains. No means are provided for draining sludge.

Method of Control. Plugging the inlets affords the only means of controlling the flow through the tanks.

By-pass. From the septic tanks the sewage flows into a gate chamber of 9-inch concrete walls, divided into two sections by a 9-inch wall 18 inches high. The first compartment is 2 feet 6 inches x 4 feet 9 inches in plan and is provided with a stop plank for use in ordinary flow. In the case of high water, sewage overflows into a second compartment, flow to which is controlled by a float controlled flap valve contained in a storm gate chamber 3 feet x 12 feet 6 inches in plan and 7 feet 7 inches deep.

A second by-pass is located in a gate chamber 6 feet 6 inches square in plan and 10 feet 6 inches deep, in which terminates the main 18-inch sewer. At the bottom of the chamber there is an 18-inch shear gate which allows the by-passing of the crude sewage in high water. All the gate chambers are closed with hinged wooden covers.

Aerating Channel and Measuring Weirs. No means for aeration are provided and no facilities for measuring the sewage flow.

Sludge Disposal Area.

No special provisions are made for disposing of the sludge, which must be pumped from the septic tanks.

Contact Filters.

After sedimentation in the septic tanks, the sewage is discharged onto coke contact filters, six in number, each with an effective area of 0.042 acre, and a total area of 0.25 acre. The filters are 43 feet square on the surface and 34 feet square on

the bottom. They are water-tight basins built of 6-inch concrete, which extends 3 feet on the sides and covers the entire bottom under which is placed 4-inch drain tile. Earth embankments separate the several units.

Filtering Material. The filtering material is blast furnace coke, which ranges in size from ½ to ¾-inch and covers the underdrains to a depth of 3 feet.

Underdrains. The underdrains comprise a main 8-inch drain at right angles to which are three lines of 4-inch vitrified sewer pipe spaced 10 feet apart. No lantern holes are provided, and no coarse material is placed over the underdraining system, although the open ends of the drains are screened with iron gauze.

Dosing Devices. To discharge sewage onto the contact filters a special apparatus is provided similar to that at Plain City, Delaware and Westerville.

Distribution Devices. The main carrier leading from the septic tanks to each of the two flooding manholes, just described, consists of 18, 15 and 8-inch pipe, respectively. From the septic tanks to a square manhole where the sewage is diverted to the second set of contact filters, the pipe is 18 inches in diameter, thence for future extension 15 inches in diameter to the first flooding manhole, following which it is 8 inches in diameter. The distribution on the filters themselves is a short length of 8-inch vitrified pipe which discharges onto the surface of the filters adjacent to one side.

Effluent Discharge. Each filter is discharged by a 6-inch siphon located in a brick manhole. These siphon chambers are similar to those at the plants just mentioned.

The purified sewage from the contact filters is discharged through 445 feet of 18-inch pipe to Oak Run. The nearest house is about ¼ mile distant. Special precautions are taken to prevent the inundation of the plant during high water. In addition to the by-passing features already described, a manhole is provided on the effluent line containing a 15-inch gate which may be closed in high water. Into this manhole also terminates the 18-inch sewer from gate chamber No. 1.

OPERATION AND EFFICIENCY.

Sanitary sewage first began to reach the plant in the summer of 1907. At the time of the inspection in November, 1907, a few connections to the sanitary sewers were producing a small quantity of sanitary sewage. There was no attempt to operate the plant on the fill-and-draw basis and the small volume of sewage was flowing through one grit chamber, both septic tanks and into the gate chamber controlling three of the coke filters. The sewage was merely flowing in a small stream onto the coke and it disappeared rapidly and wetted only a small area in each filter. The volume of sewage was not great enough to operate the plant normally and no caretaker had been engaged for the purpose.

The small volume of sewage appeared to be purified to a satisfactory degree even under the continuous operation of the plant. Moreover, it is probable that the flooding and discharging devices cannot be successfully operated and when the flow of sewage has increased considerably it will be necessary to take some steps to arrange other means for the operation of the filters.

COSTS.

The original estimate of cost for the sanitary sewers and sewage purification plant was $52,000. The approximate total final cost was $60,000, as follows:

Sewerage system, including trunk line to plant	$45,000
Septic tanks and contact filters	15,000
Total final cost	$60,000

To the end of 1907 there have been no operating expenses.

Mansfield. — General View of Contact Filters.

MANSFIELD.

The city of Mansfield is in Richland County, near the headwaters of the Rocky Fork of the Mohican River, tributary to the Muskingum River. At this point the watershed of the Rocky Fork is about 30 square miles. Mansfield is a large manufacturing center engaged chiefly in the manufacture of iron and steel products. The population of the city has increased rapidly in late years and from city records had in 1906 an estimated population of 24,000. A number of municipal improvements have been carried out, including a public water supply, street paving and the construction of sanitary and storm sewers. The public water supply was installed in the year 1870 and as it exists at the present time, comprises a system of driven wells which, according to municipal records, supply about 2,000,000 gallons daily. The city at the present time maintains 34 miles of brick, asphalt and macadam streets, 24 miles of sewers on the combined plan, and 4 miles of strictly storm sewers.

SEWERAGE.

Owing to local topography, the city is divided into high level and low level sewerage districts, respectively. For purposes of purification, to be described presently, sewage from both districts is concentrated at a point in the southeasterly part of the city adjacent to the Pennsylvania Railroad. The sewage from the high level district flows by gravity to the point of purification through an 8-inch inverted siphon 1,600 feet in length. This siphon has a difference in elevation at the two ends of 5 feet, and passes under the Pennsylvania railroad tracks. A blow-off is provided at its low point and at the entrance to the siphon there is a manhole which contains a cross wall perforated with three rows of 4-inch holes, 12 inches c. to c. and 12 inches apart vertically, placed with a view to removing coarse material which would tend to clog the siphon. In laying the 8-inch pipe under the railroad a 12-inch pipe was also placed extending from this cut to the blow-off and terminal chamber, respectively. This additional pipe allows for the future growth of the sewerage system.

Sewage from the low level district reaches the purification plant by gravity and flows into a small well on the site of the purification plant, from which it is pumped to unite with the sewage from the high level district at the point of discharge of the inverted siphon. The sewers in both districts for the greater part are on the combined plan, and are constructed of from 8 to 24-inch vitrified sewer pipe. The strictly storm sewers are brick conduits about 44x56 inches in size.

It is estimated that three-fourths of the population of Mansfield, or 18,000 persons, can connect to the present sewers for sanitary purposes, but only about 50 per cent. of the total population or 12,000 persons, are probably connected at the present time (1907). In addition to strictly residential connections a number of industrial plants are connected to the sewers for sanitary purposes. Available information, however, indicates that in no cases are manufacturing wastes discharged which materially effect the strictly domestic character of the crude sewage of the city. The principal industrial connections are listed as follows:

Character.	*Number.*
Breweries	1
Machinery and manufacturing	38
Laundries	6
Dye Works	3
Ice Plant	2
Oil Works	1

Character.	*Number.*
Livery Stables	11
Soap Works	1

CONDITIONS LEADING TO SEWAGE PURIFICATION.

The first sewers of the city were built in the year 1894, and were on the combined plan. They were gradually extended in an unsystematic way and in the year 1899 there were about 10 miles of combined and private sewers which discharged into Rocky Fork. About this date permission was asked of the State Board of Health for the construction of more sewers, which provided for the future discharge of raw sewage into Rocky Fork Creek. Prior to this, a thorough investigation had been made relative to the disposal of the sewage of the city by direct discharge into Rocky Fork. It was found that although the flow of this stream was sufficient at times to effect a satisfactory disposal of the sewage by dilution, yet at other times, especially during the drier months of the year, the flow of the stream was only about 5 cubic feet per second, and that on the basis of the necessary 3 1/3 cubic feet per second per thousand persons tributary to the sewers, it was recognized that the low water flow of the stream would provide for the satisfactory dilution of the sewage of only about 1,500 persons.

The investigation suggested that the most economical method for the future disposal of the sewage of the city, should provide for the treatment of all of the sewage at all times and that a purification plant should be so arranged that the degree of purification effected should correlate the dilution available in different seasons of the year. In view of insufficient means for proper disposal of the sewage of the city by dilution, the State Board of Health disapproved the plans for constructing additional sewers with a direct discharge into Rocky Fork.

In addition to this decision of the State Board of Health, several suits were instituted against the city on account of a nuisance alleged to be due to the discharge of crude sewage into Rocky Fork. For these reasons, the city decided to adopt plans prepared by the consulting engineers, for the purification of the entire dry weather flow of sanitary sewage. These plans were presented to the State Board of Health and were approved as presented in Jan., 1900. The sewage purification plant for the city of Mansfield constructed in view of conditions just described, was completed in 1902 and is the largest plant in the state. It consists of septic tanks, and cinder contact filters, which are operated on the fill-and-draw basis by an automatic apparatus of special design. The plant includes also a pumping station and machinery for pumping the low level sewage to the septic tanks. The pumping station also houses a garbage crematory.

EXAMINATIONS AND INSPECTIONS.

This plant was examined on July 25-27, 1906, and on May 28-30, 1907. Visits for inspection only were made in 1906 on April 26 and Dec. 26; in 1907 on Feb. 15, May 22-23, Aug. 31 and Oct. 15.

DESCRIPTION OF PLANT.

The Mansfield sewage plant is on a 14.5 acre tract of land three-fourths of a mile southeast of the center of the city and situated between the Pennsylvania Railroad and Rocky Fork. There are a few houses in the immediate vicinity and the nearest dwelling is about three-fourths of a mile distant.

Screen and Grit Chamber.

The sewage from the low level district is received in a pump well 10 feet square and constructed of concrete. The main sewer discharges 9.84 feet above the bottom of the chamber. Here the sewage is screened through a screen 10x5 feet 6 inches in area, constructed of ¾-inch wrought iron bars set 1¼ inches on centers and inclined 75 degrees to the vertical. The screen box is counterbalanced and is set in grooves, an arrangement which allows the screenings to be hoisted to the floor level of the second story of the pumping station. The screen chamber contains also an iron spiral stairway which enables the operator to descend to the screen level. This screen chamber virtually serves to intercept grit and its capacity of about 6,000 gallons is practically equivalent to 2.5 minutes run of the pumps at normal speed.

Pumping Plant.

The pumping plant comprises two Lawrence style A 7-inch centrifugal pumps. The pumps have a nominal capacity of about 1,440 gallons per minute when operated at 320 R.P.M. and when worked against a total lift of 35 feet. They are driven by a 7x7-inch vertical engine, which is rated at 25 H.P., but develops about 20 H.P. Power for operating the engines is furnished by two 25-H.P. horizontal tubular boilers which are fired with run-of-mine coal. The pumps, boilers and engine are inclosed in an ornamental brick structure which contains a garbage crematory.

Septic Tanks.

The sewage pumped from the low level district through a 12-inch force main, and that reaching the plant from the high level district by means of the inverted siphon, already described, flows into a gate chamber located at one corner of the septic tanks, whence sewage is distributed to one or more of the tanks as desired. The septic tanks are four in number and are entirely underground. Each tank is 52x92 feet 3 inches and 9 feet 6 inches deep to the crown of the arch; the depth to the maximum flow line is 7 feet 6 inches, and that to the normal flow line is 7 feet. Each has a capacity to the normal flow line of 250,000 gallons and hence the total normal capacity of the tanks is 1,000,000 gallons. To the maximum flow line, the four tanks have a capacity of 1,268,000 gallons. With four tanks in service, the period of flow originally planned was 24 hours. The tanks are constructed of stone masonry and concrete. The outside walls are 30 to 36 inches and the dividing walls 24 to 30 inches in thickness. These are built of stone masonry. The bottom of the tanks is constructed of concrete, which is in the main 6 inches thick, but is increased to 12 inches under the 18 piers which support the roof.

The tanks are covered with a groined arch concrete roof which is surmounted with loam and is seeded. The roof is supported by 18 piers in each tank, spaced 11 feet 9 inches on centers. The piers are constructed of brick and consist of five courses 28 inches square, five courses 24 inches square, and the remainder to the arch 20 inches square. The plant is practically inaccessible when in operation, although the head room from the maximum flow line to the top of the crown of the arches is 4 feet. When the tanks are drained they are accessible by ladders which may be placed in the tanks through the manholes. Each tank contains 6 manholes 3 feet in diameter with ringed iron manhole covers. The position of these manholes may be noted from Plates XXXI. and XXXII.

Inlets and Outlets. The sewage flows from the inlet gate chamber through a 24-inch iron pipe. Opposite the longitudinal center line of each tank, is a chamber constructed of 12-inch thick brick walls and with a 6-inch concrete base. The chamber is 4 feet square and 6 feet deep and contains a 12-inch sluice gate which controls the flow to a 12-inch vitrified pipe, which in entering the septic tank is

provided with four 12-inch branches which enter the tank 2 feet 6 inches below the normal flow line. Each tank has four inlets equally spaced across the tank. The main carrier, which is entirely of cast iron pipe, at tanks 3 and 4 respectively, is reduced to 18 inches. The arrangement of the inlets is shown clearly in Plate XXXIII.

The sewage is withdrawn from the septic tanks through two rows of 2-inch iron pipe spaced 12 inches c. to c. and 6 inches apart vertically. There are 98 separate small pipes in each tank and the total area of these outlets is 2.14 square feet. These outlets discharge respectively at a depth of 2 feet 6 inches and 2 feet below the normal flow line. The outlets lead to a concrete channel of trapezoidal cross section, 18 inches wide at the bottom, 2 feet wide at the top and 4 feet deep. This channel leads to the floating orifices which control the flow of sewage. The invert of the lower line of outlet pipes is located about 4 inches from the bottom of the outlet channel. The discharge from the floating orifice, which will be described presently, passes into a concrete channel which contains the main effluent carrier. As shown on the drawings Plate XXXI., this main outlet pipe is 10 inches in diameter at tank No. 1. It increases to 12 inches at tank No. 2 and is 15 inches in diameter the remainder of the distance from the septic tanks to the aerating chamber.

Sludge Drains. At the outlet of each tank, there is one 12-inch sluice gate which is operated from a brick valve chamber 3x4 feet in plan and 11 feet 10 inches deep, closed with a hinged iron cover and adjoining the septic tanks. From these chambers leads a 15-inch by-pass pipe which is laid on a 1.2 per cent. grade. One gate chamber is provided for two tanks. The elevation of the bottom of the tank is 108.0, that of the outlet drain 107.75, and therefore it is possible by this arrangement to almost empty the septic tanks. The floor of the tanks is not sloped towards the sludge drain, but is practically level.

Method of Control. The flow from each septic tank is controlled by a floating orifice. These orifices are 2x12 inches in area and are supported on an iron frame work which is held in position by two hollow galvanized iron floats which are 21x36 inches in plan and 8 inches thick. The depth of submergence of the orifices may be varied at will up to a total head of 1.5 feet.

By-pass. Leading from the siphon discharge chamber and extending completely around the tanks to the aerating chamber, is a 15-inch by-pass which is also connected to the effluent drain from the contact filters. It is thus possible to cause the crude sewage to flow directly to the contact filters or to Rocky Fork, and in view of a 15-inch connection at the toe of the aerating channel, it is possible also to by-pass the septic sewage without treatment on the contact filters.

Aerating Channel. The 15-inch outlet drain in which flows the sewage from the septic tanks terminates in a concrete chamber 4 feet wide and 15 feet long, containing at 3-foot intervals a series of steps which are intended to aerate the sewage and remove objectionable gases. A 15-inch pipe leads from the toe of the aerating chamber to the dosing device which floods the contact filters.

Measuring Weirs. At the head of the aerating channel there is a permanent weir with an iron crest; this weir has a length of 4 feet. The weir is provided with a permanent hook gage. The weir obviously records only the total flow from the septic tanks.

Ventilation. Means are provided for ventilating the septic tanks by a 10-inch pipe which extends from the top of each orifice chamber to the stack of the adjacent garbage crematory

Sludge Disposal Area.

No provisions were made in the original plans for the disposal of sludge. In 1906 the septic tanks were cleaned and the sludge discharged on to low land between the tanks and the railroad. This question is subsequently fully discussed.

FILTERS.

After sedimentation in the septic tanks and aeration, the Mansfield sewage receives its final treatment in cinder filters operated on the fill-and-draw plan. These filters are five in number and each has an area of 0.25 acre. The filters are laid out in the form of a circle, of which each unit forms a sector. The five units are separated by means of seeded earth embankments.

Filtering Material.. The filtering material is chiefly crushed cinders, which range in size from ¼ to ¾ inch. The cinders were obtained from the Pennsylvania railroad and were screened and crushed at the plant by a special apparatus. They are said to have cost 85 cents per cubic yard, in place. The total depth of filtering material is 4 feet 9 inches.

Underdrains. Each filter is underdrained with branched lines of vitrified tile, which comprises 171 feet of 4-inch tile, 169 feet of 6-inch tile, 170 feet of 8- inch tile, 16 feet of 10-inch tile and 8 feet of 12-inch tile. The drains, which form a network over the entire bottom of each unit, are laid in depressions 6 inches deep and about 20 feet apart. They are placed with open joints and are surrounded to a depth of from 4 to 9 inches with coarse cinders which range in size from ½ to 1½ inches. The general slope of the underdrainage system is 1.42 feet in 100 feet. At the end of each underdrain branch, for purposes of ventilation there is a 4-inch iron pipe which extends several inches above the surface of the filtering material. There are seven of these ventilating pipes in each filter. The underdrains are so laid that the filter is ordinarily drained completely. In case it is deemed necessary to retain a certain quantity of sewage in the underdrains, arrangements were made when the plant was built to close the regular outlet by means of a sluice gate and to cause the effluent to discharge through a second pipe located at a higher level. It appears that this arrangement has never been used.

Automatic Dosing and Discharging Apparatus. To effect the automatic operation of the filters on the fill-and-draw plan, there is an ingenious patented device which is briefly described as follows: Sewage from the aerating chamber flows to the brick gate house situated at the center of the contact filters, at which point it enters the bottom of a cylindrical chamber vertically placed. Radiating from this chamber are five 8-inch pipes which lead, respectively, to the surface of the five filters. The flow of sewage is directed on to any one filter by a revolving gate, cylindrical in shape, concentric with the chamber and machine fitted to the interior of the same. This gate has a single opening, which may be brought opposite any of the pipes which lead to the respective filters.

The effluent from the contact filters is collected in a similar cylindrical chamber, which is placed at a lower elevation. In this case, however, the flow of sewage is reversed, that is, the sewage enters the chamber through the several radiating pipes and flows to the main effluent channel through an opening in the bottom.

The movement of the gates in the two chambers is automatically controlled by means of a float, which intermittently rises and falls and operates the cylinders through a train of gears. The float is in turn actuated by the rise of sewage in the respective filter receiving sewage. Sewage is admitted to the float chamber by means of a system of piping controlled by valves, corresponding to each filter and automatically controlled by gearing. The height of rise of the float and the total movement produced through the gears is so proportioned as to cause a one-fifth revolution of the cylindrical valves in the two chambers which control the inflow and the outflow of sewage to and from the contact filters. The opening of the valve which controls the flow of sewage from a filter follows two-fifths of a revolution after the opening of the valve, which controls the ad-

mission of sewage to a given filter. This arrangement, therefore, allows one filter to be filling, another to be emptied and a third to be standing full. It is, of course, essential that the float should rise quickly as soon as sewage has filled a given filter to a predetermined elevation. This positive action is accomplished by a detent, the main feature of which is a pair of eccentric rolls. By means of a small auxiliary float, the detent is released at the proper moment.

The above constitutes the essential features of the apparatus. Provision is also made for permitting one filter to be rested for any given period. This is accomplished by segment gears, which have teeth which cover two-fifths of their circumference. These gears are attached to the valve shafts and both the main and the segment gears are actuated by a common pinion. The pinion and segment gears are so proportioned that the rise of the float will impart a two-fifth revolution to the cylindrical valve and thus skip one filter. By means of a suitable releasing device, the main gears are thrown out of action automatically when the segment gears mesh.

Distribution Devices. Sewage flows from the dosing apparatus to each filter through about 15 feet of 18-inch iron pipe, which terminates in a concrete culvert at the apex of each filter. The distribution on the surface of each filter is a wooden carrier which ranges in width from 3 feet 4 inches to 6 inches. The distributor is 6 inches deep throughout its length. The dimensions of the distributor in detail are as follows: 15 feet, 3 feet 4 inches wide; 30 feet, 2 feet 10 inches wide; 30 feet, 22 inches wide, and 30 feet, 6 inches wide. In addition to this main line, there are four 30-foot branches, two of which are 12 inches wide and two 6 inches wide. Hinged gates are provided at each change of section to control the aliquot part of the flow discharging at any given point. At each change of section wooden slabs are provided 2 feet 6 inches by 4 feet in area.

Effluent Discharge. The effluent from the contact filters flows through 220 feet of 15-inch pipe to a back flooding chamber and thence to a concrete culvert at the top of the bank about 8 feet above the average level of Rocky Fork. The back flooding chamber is 10 feet in diameter at the bottom and contains a 12-inch brick wall pierced by two 15-inch pipes, one from the contact filters and one from the toe of the aerating channel. The lower pipe is provided with a balanced flap valve which prevents the back flooding of the plant in case of high water. The filters, however, are so located that there is no immediate danger from floods, except perhaps in the case of extreme freshets.

The flow of sewage from the main low level district sewer to the plant is controlled by a float, which prevents more than a fixed volume of sewage to flow to the plant. In the case of excessive storm flows the flood gates are opened, a condition which allows the excess to reach the Rocky Fork in a raw state. On the low level sewer between the first by-pass manhole and the plant, is a second flap gate, which permits crude sewage to discharge into Rocky Fork without treatment in case more sewage flows into the low level sewer through the controlling float than is being handled by the pumps.

Sewage Flow.

The two detailed examinations of this plant and information obtained during inspections furnishes evidence of the volume of the dry weather flow of sewage. The fact that the sewers of the city are on the combined plan, of course, suggests the large influence of storms and continued wet weather on the normal sewage flow. Observations of the rate of flow as shown by weir measurements at the outlet of the septic tanks, of course, do not show the actual rate of flow, but merely the combined pumpage from the low level sewers, and natural gravity

flow from the high level sewers, respectively. Ordinarily, the combined dry weather flow through the septic tanks is about 1,000,000 gallons per day.

The first examination of the plant was carried out under strictly dry weather conditions. The by-pass at John street was inspected and it was found that all of the dry weather flow from the low level sewerage district was reaching the plant. Furthermore, careful attention was directed to the auxiliary by-pass adjacent to the plant, so that on this examination all of the dry weather sewage flow of the city was receiving treatment at the plant.

Half hourly measurements were carried out at the weir at the outlet of the septic tanks for the period from 6:00 o'clock A. M. July 25, to 5:30 o'clock A. M. July 27, 1906. These measurements showed but slight difference in the rate of total flow, which in this case ranged from 817,000 to 1,122,000 gallons and averaged 999,000 gallons in 24 hours. It is to be recalled that the floating orifices at the outlets of the septic tanks are intended to cause a fairly constant flow from the tanks and as a consequence the depth of sewage in the septic tanks increases during the hours of maximum flow and falls again to the lesser depth of flow during the night.

These measurements, of course, afforded information as to the combined flow from the two sewerage districts. The flow from the high level district was likewise measured at half hourly intervals for the same period of time. The average flow from the high level district or more strictly the residential section of the city was on this examination 153,000 gallons, the maximum rate was 189,000 and the minimum was 37,000 gallons. The difference between the weir readings at the plant and at the entrance to the inverted siphon roughly show the amount of pumpage which on this examination was about 800,000 gallons or about 81 per cent. of the total flow of the city. The total dry weather flow on this examination was about 83 gallons per capita. In this connection, it should be noted that of the total flow from the low level district, about 150,000 gallons of ground water were known to gain admission to the sewers through a connection from the local brewery.

Similar gagings of the sewage flow were made on the second examination, almost a year later. Owing to stormy weather, considerable difficulty was experienced in setting the weir for the high level sewage. On the day of the examination, however, there was no rainfall, but as was evident from the sewage flow and the general appearance of the sewage, there was considerable leakage into the sewers. The measurements on this examination lasted for 24 hours only, from 12:01 o'clock A. M. to 11:30 o'clock P. M., May 29, 1907. Similar observations were carried out at the outlet weir from the septic tanks. The rate of flow in the case of the high level sewage averaged 275,000 gallons in 24 hours and the maximum and minimum rates were 330,000 and 248,000 gallons, respectively. The total flow at the outlet from the septic tanks averaged 1,058,000 gallons and showed a maximum at 8:00 o'clock A. M. May 30th of 1,245,000 gallons and a minimum at from 2:30 o'clock A. M. to 4:30 o'clock A. M., May 30 of 650,000 gallons. Corresponding minima were noted for the high level district. The total pumpage on this examination, estimated by difference, was about 753,000 gallons. The average flow during the 24 hours of the test was 88 gallons per person tributary. Although somewhat obscured by the fact that the examination was made just after a period of wet weather, it is to be remarked that in the spring of 1907, prior to this examination the flow of ground water from the brewery was cut off.

The above data indicate the general relation of the high and low level sewage flows as have obtained during the period covered by this investigation. In the summer of 1907, there was made a further change in relation to the sewage flow from the two districts, when the sewage from Park Street, which drains

a thickly settled area of the city was caused to flow into the high level sewers and thus to reach the purification plant by gravity. At the present time, (1907) the sewage flow of the city has not increased since the system was first installed sufficiently to warrant any increase in the capacity of the inverted siphon.

During wet weather and storms the sewage flow is greatly increased and large volumes of storm water flow into Rocky Fork through the automatically operated by-pass at John Street. Overflow manholes are also provided in the case of a number of the sewers; in wet weather sewage flows through these overflows into small water courses, and eventually to Rocky Fork.

COMPOSITION OF CRUDE SEWAGE.

Since the sanitary sewers of the city are on the combined plan it is apparent that there is an intimate relation between the rainfall and the elevation of the ground water and the composition of the sewage.

The first examination of the plant, as before stated, was carried out strictly under dry weather conditions. Samples of the sewage from the high level district were collected at the entrance to the siphon at half hourly intervals for a period of twenty-four hours. Similarly, samples of the low level sewage were collected from a manhole on the trunk sewer a short distance from the pump well for a period of 48 hours. The former samples were mixed to form an average sample corresponding to the day and night flow, respectively, in conformity to the varying rate of flow, as shown by weir measurements. The day period was considered to be from 6:00 o'clock A. M. to 9:30 o'clock P. M. and the night flow from 10:00 o'clock P. M. to 5:30 o'clock A. M. It was not possible to proportion the samples from the low level district to correspond to the changing rate of sewage flow and hence the half hourly portions were mixed in equal volumes to form the average. The division of the day and night periods was the same as in the case of the high level sewage. At four hourly intervals throughout the examination, dissolved oxygen samples were collected in the case of both sewages. The analytical data obtained on this examination, indicated first that the Mansfield sewage is very dilute as it contained but small quantities of organic matter and suspended matters. Furthermore, due presumably to ground water leakage, in practically all of the samples of the low level district sewage, dissolved oxygen was present in quantities which ranged from 0.0 to 2.3 parts per million. The high level sewage appeared to be less influenced by leakage and was substantially a fairly strong domestic sewage. It also contained dissolved oxygen, but in lesser quantities than in the case of the low level sewage. The oxygenation of the Mansfield sewage is shown by the results in the next table.

TABLE NO. 53.

Dissolved Oxygen in the Crude Mansfield Sewages July 25-27, 1906.

Hours.	Dissolved Oxygen — Parts Per Million. Crude Sewage.	
	Low Level.	High. Level.
8:00 A. M.	2.3	0.0
12:00 Noon	0.0	0.2
4:00 P. M.	0.7	0.2
8:00 P. M.	1.1	0.2
12:00 Mid.	1.9	0.2
4:00 A. M.	1.8	1.7
8:00 A. M.	0.0	.....
12:00 Noon	0.9	.....
4:00 P. M.	1.0	.....
8:00 P. M.	0.0	.....
12:00 Mid.	0.0	.....
4:00 A. M.	0.2	.....

The second detailed examination lasted 24 hours and again included the collection of average samples of the sewage from both sewerage districts for a period of 24 hours. The method of sampling and the proportioning of the individual portions were the same as on the first examination. Evidence from analyses of the samples again indicated the dilute character of the crude Mansfield sewage. On this examination, during which there was somewhat greater leakage, practically all of the samples of the crude sewage contained dissolved oxygen. In the case of the high level sewage the dissolved oxygen ranged from 0.3 to 7.1 and the low level sewage from 0.9 to 4.3 parts per million. The dissolved oxygen results obtained on this examination are listed in Table No. 54.

TABLE NO. 54.

Dissolved Oxygen in Mansfield Sewages.

Hour — May 29, 1907.	Parts Per Million.	
	High. Level.	Low Level.
12:01 A. M.	5.8	0.9
4:00 A. M.	7.1	4.3
8:00 A. M.	4.6	2.7
12:00 Noon	0.3	1.7
4:00 P. M.	2.0	1.3
8:00 P. M.	3.0	1.7

Analytical evidence from this examination illustrates the high dilution sustained by the crude sewage at this plant. The night sewages from 12:00 o'clock

midnight to 8:00 o'clock A. M. contained both nitrogen as nitrates and nitrites and were low in organic matters. While the day sewages were free from nitrified nitrogen, yet the low oxygen consumed and the low suspended matters are particularly suggestive of the general weakness of the crude sewage. The analytical data appended to this discussion of the Mansfield plant are particularly suggestive in the premises.

The above general comments suggest the character of the Mansfield sewage on these two examinations, both of which were carried out under substantially dry weather conditions. During storms, of course, the sewage carries large quantities of mineral matter and is decidedly more dilute than the appended data indicate.

OPERATION.

The board of public service has general oversight over the sewage purification plant which is under the general supervision of the city engineer. During this investigation, the actual operation of the plant has been in charge of three stationary engineers, who are employed on eight hour shifts. This force operates the boilers and pumps and attends to duties incidental to the operation of the garbage crematory. In the early history of the plant, in addition to the pumping station force there was a superintendent in charge of the septic tanks and contact filters. Since the latter part of the year 1905, however, no one has been employed to attend to the operation of the sewage plant alone.

The duties of the present force are chiefly in the pumping station, although the operator on the day shift occasionally devotes some time to the septic tanks and to the automatic apparatus. From time to time additional labor is employed to clean the contact filters and to take care of other matters relating to the upkeep of the plant.

Storm Overflow at John Street.

It was found during this investigation that after all storms it is necessary to inspect the flap gates which control the by-passing of the low level sewage at John Street. During storms the sewage, of course, contains large quantities of mineral matter and slit which tend to clog the gates and unless these are carefully inspected, the crude sewage discharges directly into the creek. On the first general inspection of the plant and on several other occasions during this investigation, it was found that proper attention had not been paid to this feature and that part of the dry weather sewage flow was reaching Rocky Fork.

Pumping Plant.

The presence of a second by-pass adjacent to the plant has been mentioned, and throughout the period of this investigation it was found that frequently there was a certain laxity in the operation of the pumps so that the steam pressure would not be sufficient to prevent the entrance of crude sewage into Rocky Fork at his point. During wet weather on the inspection of December 26, 1906, for example, it was found that the pumps were being operated at half speed and that sewage was being by-passed at John Street and at the flap valve near the plant. Indication was strong that at times the plant did not handle the entire dry weather flow. In the spring of 1907, the screen well was examined and it was found that the suction of the centrifugal pumps was clogged with sludge. The well was cleaned and clogging removed and a subsequent pumping test showed that the pumping plant was capable of handling the desired volume of sewage. It was found that it was necessary to operate with about 80 pounds of steam and a vacuum on the suction of the centrifugal pumps of from 15 to 18 inches.

With a view to obtaining a continuous record of the method of handling the pumping plant, the city engineer in the summer of 1907 installed a self-recording vacuum gage. Since that time much better conditions have prevailed at the plant and less of the dry weather sewage flow has reached the creek through the by-pass near the plant.

Screening.

Very little attention is paid to the screening of the crude sewage. On the first detailed examination, it was learned that the wet screenings are removed from the well not more often than once in two months and at times not more than four or five times a year. It is evident that the ¾-inch screen in conjunction with the centrifugal pumps does not seriously clog. On the second detailed examination it was brought out that while the screen requires very infrequent cleaning, yet the clogging of the suction of the centrifugal pumps suggests that the small screen chamber serves to cause the deposition of considerable material from the crude sewage.

Sewage from the high level district enters the septic tanks without screening.

Septic Tanks.

The septic tanks at Mansfield were operated for four years up to the spring of 1906 without cleaning. Sludge was then removed from the tanks as will be presently discussed. Prior to this investigation, and during the year 1906, four tanks were in service to which the sewage from the low level district was pumped continuously for 24 hours a day. This corresponds to a period of flow of 24 hours, and a linear velocity of 0.33 m. m. per second. In December, 1906, and continuing to the summer of 1907, two tanks were used, corresponding to a 12-hour period of flow. In the summer of 1907, and continuing to the end of this investigation, three tanks have been used as was the case on the final inspection of Oct. 15, 1907.

Floating Orifices. In the spring of 1906, when the septic tanks were cleaned it was found that the floats which support the regulating orifices were rusted and required renewal. Practically at all times during this investigation, due to the use of two tanks only, and also in part to stoppages in the 2-inch outlet pipes, to be discussed presently, the floats have arisen to a maximum. Moreover, it has not been possible to change the depth of submergence of the orifices since the movable plates have been rusted during five years of service.

Stoppages in Outlets. The clogging of the small 2-inch outlets of the septic tanks was primarily the cause for the removal of sludge in the spring of 1906, when the tanks were cleaned and the outlet pipes washed with a hose, and as well the shallow channel in which these pipes terminate. After this cleaning in the spring of 1906, the outlets continued free from clogging until in the latter part of December, 1906, when it was necessary to wash the outer channel and the outlets with water from a hose.

On May 21, 1907, about five months later the outlets of septic tanks Nos. 1 and 2, which had alone been in service for the past five months again began to clog to such an extent that the available head would not force the sewage through the tanks. The tanks were then drawn down and the outlets examined. It was found that the majority of the holes in both lines were clogged with a pasty mass and upon further inspection there was found in the outlet channel a heavy deposit of sludge, sufficient completely to cover the lower row of holes and extending up to the invert of the upper row. The quantity of sludge in the septic tanks themselves was very slight. The outlet channels were then cleaned with a fire hose and the sludge was forced back into the septic tanks. In the summer of 1907, at a time when the use of four tanks was again resumed, it was found that the 2-inch outlets of the tanks previously in use were again clogged with suspended matters

and it was again necessary to flush the outlet channel. On the final inspection of October 15, 1907, the movement of sludge from the septic tanks had again caused a clogging of the outlet pipes, a condition which necessitated further cleaning.

Sludge Disposal.

After about four years of service the accumulated sludge was removed from the Mansfield septic tanks and as previously mentioned the stoppages of the outlet pipes primarily suggested the removal of the sludge. Subsequent developments with reference to stoppages in the small outlet pipes, as found during this investigation suggested that the actual clogging of the outlet pipes was not from an accumulation of sludge on the inside, but rather from the deposition of sludge in the shallow outlet channel, which as may be noted from the drawings is only about 4 inches below the invert of the lower row of outlet pipes. Moreover, the actual depth of sludge found in the tanks is stated to have ranged from 2 to 3 feet only, and since the lower row of 2-inch outlet pipes is 5 feet above the floor of the tanks, it is difficult to understand how a stoppage of the septic tanks could have taken place on account of the accumulation of sludge within the tanks, especially since the mobile nature of the sludge would presumably not allow of its deposition with a slanting surface.

The cleaning of the septic tanks was begun about April 23, 1906, and was continued for several days. When operations were begun, Rocky Fork was in flood and it was decided to discharge as much of the sludge as possible directly into the stream. Accordingly, the supernatant sewage was drawn off from one of the septic tanks, following which the sludge valve was opened and men were sent into the tank to direct the sludge towards the sludge outlet. It was found that the deposit was of such a pasty consistency that it would not readily flow and that in order to take advantage of this method of removing the sludge from the tank it was necessary to dilute it with sewage. After perhaps about 500 cubic yards of sludge had been removed from the tanks in this manner, it was thought unwise to continue this method of disposal since the waters of the creek had receded and since the dilution afforded by the creek under normal flow would by no means be sufficient to effect the satisfactory disposal of the sludge without creating a nuisance. After abandoning this plan, it was decided to use the sludge as a fill for waste land adjacent to the septic tanks. To effect this, a block and tackle was erected over one of the manholes, barrels were lowered into the tanks and were filled by five men working with buckets. The capacity of this arrangement was about 250 barrels for an eight hour day. The force employed comprised seven men and one horse in addition to the foreman. The filled barrels were hoisted to the surface and caused to discharge through a sluice onto a steep embankment which led to the low land adjacent to the septic tanks.

The sludge possessed a deep black color but was without appreciable odor. In fact the wind blowing directly off the pool of sludge carried practically no odor whatever. The septic sludge in these tanks was about four years old and apparently was so thoroughly worked over by bacterial agencies, that the putrescible matters had been very thoroughly destroyed. Samples of the sludge were collected for analysis, the results of which were as follows:

TABLE NO. 55.

Analysis of Mansfield Sludge.

Specific gravity	1.11
Weight per cubic foot (pounds)	69.2
Per cent water	80.8

TABLE NO. 55 — Concluded.

Per cent volatile matter	3.6
Per cent ferric oxide (Fe_2O_3)	1.1
Per cent iron (Fe) not as FeS	0.28
Per cent ferrous sulphide	0.76
Per cent nitrogen	1.03
Per cent ether-soluble matter	4.7

It is evident from these data that the Mansfield sludge was a typical septic sludge practically of a similar composition to that found in the Columbus experiments when the septic tanks were cleaned out after eleven months operation. Of particular interest and importance, with reference to the disposal of sludge is the fact that septic sludge as indicated by these Mansfield experiences is not obnoxious, that is, under normal conditions, or after sufficiently prolonged bacterial action, the greater portion of the putrescible matters present in the sludge when freshly deposited have been removed to such an extent that the resulting sludge appears as a granular mass, more homogeneous than the original deposit, and of such a nature that it may safely be removed without the liability of a nuisance from odors. It is evident from the above that to insure freedom from odors, periods between cleanings of the septic tanks should be as long as possible in order to take advantage of the beneficial effect of bacterial activities upon the putrefactive matter which is deposited from sewage, which has been settled at fairly low velocities. A further point of interest in relation to the disposal of sludge at Mansfield, is the fact that exposed in thin layers to the air for a period of about four days the sludge lost its black color, or in other words the sulphide or iron acted as a carrier of oxygen, so that the dried mass was practically void of odors of putrefaction and was in effect more to be classed as humus matter.

The total quantity of sludge removed from the Mansfield septic tanks is estimated at 1200 cubic yards. The cost of sludge disposal is estimated at about 50 cents per cubic yard. Certain details of this cost will be discussed below.

Contact Filters.

The operation of the contact filters is, of course, essentially automatic and practically the only attention necessary is the removal of sludge deposits from the surface and occasional raking. During this investigation all five filters have been in service and based on the average daily rate of combined sewage flow of 1,000,000 gallons the rate of filtration has been 800,000 gallons per acre in 24 hours. The contact filter area of 1.25 acre corresponds to about 9,600 persons tributary per acre or 2,000 per acre-foot.

Surface Clogging. The clogging of the filtering material, owing to the suspended matters carried by the applied septic sewage during this investigation has necessitated some additional labor in the operation of the contact filters. In the spring of 1906, it was stated by the officials that the contact filters were dug up and the clogged material was removed, washed and replaced. The discolored material is said to have extended to a depth of 2 feet and below this point it was stated that the material appeared clean and in serviceable condition. On the inspection of April 26, 1906, at within a radius of perhaps 15 feet from the distributor troughs, the surfaces of the contact filters were noted to be clogged with clayey material. It was stated that this deposit extends downward to perhaps a depth of 15 inches. On the first detailed examination, very little clogging was noted on the surface of the contact filters and there was no odor from the filtering material. On December 26, 1906, an inspection made after a considerable

period of violent action in the septic tanks during which large quantities of black suspended matters passed out of the tanks, there was marked evidence of clogging on the contact filters. The sewage pooled and after passing over the clogged superficial areas gradually increased the clogged areas. At this time, the penetration of the suspended matters was considered to be about 8 inches. It is evident that the filters were not receiving proper care and it was stated that for some time past no one had been employed to have charge of the operation of the contact filters. Similar conditions as to surface clogging were found on the detailed examination in May, 1907. In the early part of this month, surface clogging increased so that it was deemed advisable to clean the filters. Two men are said to have been required for the work which lasted five days. The sludge is said to have ranged in thickness from 2 to 8 inches, although in many places there were pockets in which the heavily sludged filtering material is said to have been noted 2 feet beneath the surface. These deep pockets left many depressions in the filters all of which on this visit were very seriously ponded. The drying sludge was piled up around the plant, and at a distance of about 100 feet very offensive odors could be detected. The air was clear and warm and there was no wind.

With a view to learning definitely the degree of clogging, a test pit was dug 4 feet in depth at a point in one of the filters beneath the area of apparently maximum clogging. The general appearance of the material was practically the same after the removal of the upper few inches. In those areas away from the distributors there was practically very little clogging. The material in these sections of the filter below 3 inches was porous, but underneath the distributors it was noticeably more compacted and was surrounded by a slimy gelatinous mass which, no doubt, tended materially to reduce the holding capacity of the filters. It was further remarked that the sludged material dried very rapidly on exposure to the air. On the next visit, on August 31, 1907, the clogged condition of the surfaces of the contact filters was perhaps more pronounced than formerly, apparently but little attention had been paid to the operation of the contact filters. Vegetation had been allowed to develop although recently it appeared that four of the filters had been cleaned. Ponding was strongly in evidence and a heavy coating of black sludge was noticeable at the discharge points of the distributors. Considerable odor was noticeable from such of the filters as had not been cleaned. The frequent cleaning of the surface material, the removal of sludge deposits and at times a considerable quantity of the cinders themselves has decreased the thickness of the filtering material so that the concrete discharging slabs are now about 6 inches above the surface of the main body of the filtering material. Practically similar conditions were noticeable on the final inspection. It has not been possible to present an accurate record of the quantity of material removed from the contact filters, nor of the cost of the labor entailed, as no detailed records are kept in regard to these matters. It is to be stated that the clogged appearance of the filters, while due in a large part to the lack of attention is also attributable to the discharge of large quantities of suspended matters from the septic tanks.

Percentage of Voids. The clogging of the cinder filtering material, just discussed naturally suggests a loss in the holding capacity of the filters. On each examination observations were made from which could be drawn approximate conclusions as to the quantity of sewage corresponding to each filling of the respective filters. These data were obtained by keeping a careful record of the operation of the automatic apparatus and at the same time a record of the flow of septic sewage. The volume of sewage necessary to trip the automatic apparatus for the five filters on both detailed examinations is shown in Table

No. 56. Reference to this table indicates that the holding capacity of the filters in 1907 ranged from about 92,000 to perhaps 110,000 gallons. Perhaps Nos. 2 and 3 appeared to be the most seriously clogged. Comparing the holding capacity of the filters for the years 1906 and 1907, it is apparent that in almost each instance there has been a decided loss in capacity. Apparently the reduction in voids is not yet sufficiently great measurably to effect the efficiency of the filters.

TABLE NO. 56.

Capacity of Contact Filters.

Filter No.	Holding Capacity. Gallons.	
	1906.	1907.
1	110,000	115,000
	112,000	.....
2	112,000	92,000
	110,000	97,000
	.....	93,000
3	126,000	93,000
	133,000	104,000
4	129,000	96,000
	.....	101,000
5	111,000	107,000
	112,000	107,000

NOTE: Night observations omitted owing to probable inaccuracy in measurements.

Length of Cycles. Observations of the operation of the automatic apparatus carried out on the two detailed examinations have afforded information as to the length of the several cycles in the operation of the contact filters. The capacity results just presented, of course, suggest that during this investigation the filling and the standing full periods have decreased decidedly. On the detailed examination of 1907, for 24 hours five filters were in service. Since the flow from the septic tanks, with the exception of the early morning hours, is substantially a constant, the several cycles are approximately the same duration, of which the following are representative: filling 2.25 hours, standing full 2.25 hours, and resting 5 hours.

Automatic Apparatus. The apparatus designed to effect the automatic operation of the contact filters, has in general been in very successful operation. Some time prior to this investigation, however, the segment gear was removed, as it was stated that at times the gear teeth did not mesh accurately and tended to bind the machinery. During the first detailed examination of 48 hours duration the automatic apparatus rotated the incoming sewage accurately with one exception and in this case the float did not rise sufficiently to change the valves. It appears that such conditions have at times obtained and it is then necessary, of course, for some one to release the clutch and cause the sewage to change its course. To prevent serious difficulty, should such conditions obtain at night, over-

flows were provided from one filter to another through small pipes in the dividing embankments. On the second detailed examination the automatic apparatus was found to be operating accurately. No trouble has been experienced at Mansfield as was the case at Lakewood, with reference to the entrance of silt between the movable and fixed cylinders. Aside from occasionally oiling the apparatus, it practically requires no attention.

Failure of Outfall Culvert. On the visit of December 26, 1907, it was learned that owing to high water the gravel supporting the outfall concrete culvert was washed away and the entire culvert failed, thus exposing the effluent pipe. Large masses of concrete have fallen into the Rocky Fork.

EFFICIENCY.

The general object of the detailed examinations was to learn the efficiency of the septic tanks in the preparatory treatment of the crude Mansfield sewage under dry weather conditions, to inquire into the effect of aerating the septic sewage and to learn definitely the degree of final purification effected by the cinder contact filters.

Septic Tanks.

On the first visit during which was witnessed the removal of sludge from the septic tanks, it was apparent that the small volume of sludge while due in part to the destruction of the crude material originally deposited was in a large part accounted for by the fact that considerable suspended matter has passed out of the tanks with the effluent as was further indicated by the surface clogging of the contact filters, and by the clogging of the small outlet pipes and effluent channel to which was ascribed a necessity for cleaning the tanks as already stated. On the detailed examinations, therefore, it was considered of marked interest to obtain definite average analytical data as to the average efficiency of the tanks in the removal of suspended matters.

Collection of Effluent Samples. On the first detailed examination, for the first 24 hours samples of the septic effluent, collected at half hourly intervals, were mixed in equal portions at the end of periods corresponding to the flooding of the several contact filters, or in other words, the samples of septic sewage were respective averages of the sewage applied to each of the five contact filters. On the second day, the half hourly portions were mixed in equal portions for a period of 12 hours, namely from 2:30 o'clock P. M. until 2:30 o'clock A. M. This 12-hour average sample was collected to learn whether there was a substantial mixing effect in the tanks so that the effluent would actually show very little variation in average composition.

On the second detailed examination which was one of 24 hours duration, samples of the septic effluent were similarly collected, corresponding to the sewage applied to the five contact filters. The sampling of the septic sewage in both cases was begun practically 12 hours after that of the crude sewage to allow for the period of flow of the septic tanks. On this examination there were two separate samples of septic sewage collected as influents for each filter. These were mixed in equal portions to form the average influent for the respective filters for the 24 hours.

General Character of Effluent. On the first detailed examination there was noted a decided odor from the septic sewage, as the effluent flows over the weir into the aerating channel, an odor which was noticeable at a distance of some one hundred feet. Similar odors were noted on the visit of December 26, 1906, and on the second detailed examination it was especially remarked that the septic

effluent in mass was black in color and possessed an odor which could be detected at a distance of 50 feet. Generally on the visits to the plant the septic effluent has been black and has had a decided odor of hydrogen sulphide. Practically no odors whatever have been noticed adjacent to the septic tank themselves.

Removal of Suspended Matters. The clogged condition of the contact filters and the stoppages in the outlets of the septic tanks have already suggested that at times considerable suspended matter is contained in the effluent from the septic tanks. On the two detailed examinations analytical evidence was obtained as regards the efficiency of the septic tanks in the removal of suspended matters. On the first detailed examination four septic tanks were in service, and the average of the two 24-hour sampling periods showed suspended matters in the effluent from the septic tanks of only 34 parts per million. On the 12-hour sampling period which followed the suspended matter was 42 parts per million. The weighted average sample of crude sewage contained only 34 parts per million of total suspended matter and hence after passing through the septic tanks the suspended matter content was but little changed.

The data obtained on the second detailed examination, however, gave more definite information as to the variation in the suspended matter contained in the septic effluent at different hours of the day and suggested the cause for the stoppages of the outlets and the clogging of the surface of the contact filtering material. Analytical results from the analyses of the septic sewage and the crude sewage on the second detailed examination as regards suspended matters are shown in the next table. It is of interest to note the decided variation in the suspended matters and the fact that the efficiency of the tanks in the removal of suspended matters was negative.

It is to be recalled that on this examination two tanks were in service. It was expected that the use of two tanks would cause the sewage to have less odor and would further reduce bacterial activities in the deposits of sludge. In other words it was assumed that the period of flow of the four tanks in service was practically twice as great as necessary to obtain a septic sewage of satisfactory character. The analytical data, shown below indicate that in practically every case the effluent from the septic tanks contained more suspended matters than was applied. Perhaps these conditions are to be ascribed to the renewed septic activity which occurs in sludge shortly after the advent of warmer weather. Apparently the decreased period of flow did not have a material effect upon the suspended matters, possibly because the critical period is probably much less than the 12-hour period which prevailed during this detailed examination

TABLE NO. 57.

Suspended Matters in Crude and Septic Sewages on May 29-30, 1907.

Source.	Parts Per Million. Suspended Matters.	
	Total.	Volatile.
Crude Sewage —		
High Level	50	38
Low Level	81	53
Composite	74	55

TABLE NO 57 — Concluded.

Source.	Parts Per Million. Suspended Matters.	
	Total.	Volatile.
Septic Sewage, (Influent Contact Filters) —		
12:30 P. M. to 2:44 P. M.		
12:03 A. M. to 2:40 A. M.	85	43
2:49 P. M. to 5:00 P. M.		
2:40 A. M. to 5:22 A. M.	135	53
5:00 P. M. to 7:24 P. M.		
5:22 A. M. to 8:02 A. M.	93	50
7:24 P. M. to 9:48 P. M.		
8:02 A. M. to 10:24 A. M.	135	53
9:48 P. M. to 12:03 A. M.		
10:24 A. M. to 12:31 P. M.	104	54

NOTE — Septic sewage average influent for two fillings for each filter.

On further visits to the plant, during this investigation, the periodic discharge of suspended matter from the septic tanks was always noted, as is, of course, suggested by the feature of surface clogging in the contact filters, as already discussed.

Effect of Aeration. The constructional features which are intended to aerate the septic effluent before its application to the contact filters, were intended to remove gases inimical to subsequent purification, as well as to introduce a certain quantity of dissolved oxygen. On the first detailed examination it was found that ordinarily the effluent flowing directly from the septic tanks contained no dissolved oxygen, although of all of the twelve samples collected during the 48 hours of the tests, five contained small quantities of dissolved oxygen which ranged from 0.8 to 1.8 parts per million. After passing the aerators about 50 per cent. of the samples contained small quantities of dissolved oxygen which ranged from 0.4 to 3.4 parts per million. Information in this regard obtained on the second detailed examination showed practically the same results and was especially instructive as suggesting the general weakness of the Mansfield crude sewage. On this examination in only one instance dissolved oxygen was absent. The maximum quantity before aeration was 1.5 parts per million and after aeration the maximum quantity was 4.5 parts per million. At the temperature of the sewage at 55 degrees F., the percentage saturation of the septic sewage before aeration was only 14, after aeration 30, an increase of only 16 per cent. The change in the temperature produced by aeration was so slight as to be practically negligible. Representative data regarding the efficiency of the aeration of the Mansfield septic sewage as obtained on the second detailed examination are shown in the following table. By comparing these results with similar data for the crude sewage as shown in Table No. 53, it is evident that on this examination dissolved oxygen present in the applied sewage was not destroyed in the passage of the sewage through the tanks.

TABLE NO. 58.

Aeration of Septic Sewage.

May 29, 1907 — Hour.	Temp. Deg. F.			Parts Per Million.	
		Septic Effluent.			
	Air.	Before Aera.	After Aera.	Before Aeration.	After Aeration.
12:01 A. M.	48	55	55	1.5	4.5
4:00 A. M.	48	55	55	1.1	3.3
8:00 A. M.	60	55	55	0.8	2.6
12:00 Noon	66	55	55	0.1	1.3
4:00 P. M.	72	56	55	0.0	3.5
8:00 P. M.	56	56	56	3.1	2.4

Contact Filters.

On all of the visits to the plant the effluent from the contact filters has been of a very satisfactory appearance, and has been non-putrescible. The suspended matters have been normally low for contact filter effluent, and there has been no odor whatever near the discharge of the effluent into Rocky Fork. In addition to analytical evidence obtained on the two detailed examinations a few daily putrescibility tests were carried out at the plant. These tests invariably showed that the effluent was to be considered satisfactory in this respect. The results of the analysis of samples collected on the two detailed examinations are presented beyond, together with similar data obtained during this investigation. On each test separate samples were collected to learn the character of the effluent from each of the five filters.

As the analyses indicate, the purification effected by the filters has produced a very satisfactory effluent, containing but small quantities of organic matter, of low turbidity, and as naturally expected, but relatively small quantities of nitrates. The decided reduction in organic nitrogen is perhaps worthy of special comment. The analytical data also show that the effluent from the contact filters invariably contain small quantities of dissolved oxygen.

SUMMARY.

The results of this investigation indicate that the sanitary sewage of Mansfield has been satisfactorily purified without nuisance and that the plant has completely abated nuisances which formerly existed due to the direct discharge of crude sewage into Rocky Fork. Evidence was obtained, however, which shows that at times not all of the dry weather flow of domestic sewage has been treated, but that it has flowed into Rocky Fork without treatment at the overflow at John Street and at the flap gate near the plant. The efficiency of the plant is high when judged from the character of the effluent of the contact filters, but in considering the operation of the plant as a whole, an allowance should be made for the failure to treat the entire sewage flow of the city.

The somewhat high cost of sewage purification at Mansfield, due chiefly to the necessity for pumping, as discussed presently, suggests that considerable

economy could be effected were internal combustion engines substituted for steam. The operation of the plant could then be carried out with fewer operators and the saving thus accomplished would be available to engage an attendant whose sole duty would comprise the operation of those features of the plant which relate exclusively to the purification of the sewage. The lack of proper supervision of the septic tanks and of the contact filters constitute the chief criticism of this plant.

Several interesting points are indicated by Mansfield experiences. Screening has not proven efficient for the Mansfield low level sewage and the introduction of the small chamber for the reception of the grit has been found unnecessary and in part a detriment to pumping operations, as indicated by the clogging of the suction of the pumps. The septic tanks have not been especially efficient in the removal of suspended matter as evident from results obtained in recent years. Although the removal of sludge was probably not obligatory, the tanks have not been particularly effective in destroying sludge as is indicated by the serious clogging of the contact filters. Stoppages in the outlets have been of frequent occurrence in 1907 and indicate that small pipes cannot successfully be located at such relatively short distances above the bottom of outlet channels. The controlling devices for causing a constant flow from the tanks have ordinarily been successful, but owing to lack of care have gradually deteriorated from rust. Their condition suggests that care required for all kinds of machinery is necessary for devices of this type, if they are to continue in successful operation. It should be noted that the galvanized iron floats required renewal after four years of service. Aeration of the septic sewage has not been efficient as very little oxygen is introduced in the septic sewage by this means. Moreover, the aerating device has caused considerable odor in its immediate vicinity.

The automatic apparatus for controlling the operation of the contact filters has generally been entirely successful; although the two-fifths segment gear has not proved entirely satisfactory. The contact filters have been seriously clogged in recent years due to the discharge of large quantities of suspended matter from the septic tanks, and while the surface material has been occasionally cleaned, the filters have not received sufficient attention. There has further been a decided loss in interstitial capacity. The effluent from the contact filters has been purified to a non-putrescible state and in view of the lack of supervision, it is quite probable that the general weakness of the crude Mansfield sewage is intimately related to the excellent degree of purification afforded by the contact filters.

In conclusion, attention may very properly be directed to the fact that the general poor appearance of the plant and the chief criticism of its operation, relates to the lack of necessary supervision on the part of the city officials. To improve operating conditions at Mansfield it would unquestionably be wise to appoint a caretaker to have full charge of the actual operation of the sewage plant as was the case during its early history.

COSTS.

The engineer's estimate of the cost of the Mansfield sewage purification plant and garbage crematory was $85,547, of which $12,000 is chargeable to garbage disposal. The septic tanks cost $15,870 and are of 1,000,000 gallons capacity. The contact filters and appurtenances cost $19,850, or at the rate of about $16,000 per acre. The cinder filtering material is said to have cost 85 cents per cubic yard in place. Detailed estimates of cost were as follows:

TABLE NO. 59.

Estimated Cost of Sewage Purification and Garbage Disposal.

Low level outfall	$11,500
High level siphon	2,000
Pump, well and screens	2,550
Pumping station and crematory	9,000
Pumps and boilers	3,000
Septic tanks	15,870
Filters	19,850
Land	8,000
Garbage crematory	6,000
Total	$77,770
Ten per cent added for contingencies	7,777
Total	$85,547

Operating expenses for the years 1906 and 1907 were about $5,644 and $5,260, respectively. Of these costs, the amounts chargeable to salaries and extra labor for the two years were about $2,720 and $2,800, respectively. Coal is a large item which was about $2,923 in 1906 and $2,460 in 1907. It is not possible to state these costs in terms of million gallons of sewage treated owing to uncertainties in the actual volume of sewage pumped. The operating expenses per person tributary are 47 cents and 44 cents, respectively for the years 1906 and 1907.

Sludge Disposal.

Included in the above operating expenses for the year 1906, is the cost of removing sludge from the septic tanks. Seven men and one horse were engaged in the work which comprised the removal of about 1200 cubic yards of septic sludge.

With five men inside the tank filling buckets and two above, one directing the discharge of the barrels and the other leading the horse, it was found feasible to average 250 barrels per day of 8 hours, or about 40 cubic yards. The maximum quantity removed in one day is said to have been 280 barrels, or about 41.5 cubic yards. The average cost per day was 6 men at $2.00 and one man and horse at $3.00 or $15.00. The erection of a derrick for hoisting the sludge cost about $40. The average labor cost per cubic yard was about 37.5 cents, to which should be added the cost of the derrick for each of the 1200 cubic yards of sludge removed, so that the total cost averaged about 50 cents per cubic yard.

TABLE NO. 60.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.													
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Fats.	
					Organic.											
			Total.	Dissolved.	Total.	Dissolved.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Volatile.				
Crude Sewage (Low Level.)																
July 25, 1906.....	6:00 A.- 9:30 P.	68	22	14	5.4	1.8	6.0	1.00	0.0	34	33	26	3	4.7	19	
July 25-26, 1906..	10:00 P.- 5:30 A.	67	16	11	4.8	2.2	7.6	0.22	0.2	26	32	26	2	1.9	19	
Average	6;00 A.- 5:30 A.	68	20	13	5.2	1.9	6.5	0.74	0.1	31	33	26	3	3.8	19	
May 29, 1907.....	12:01 A.- 8:00 A.	62	13	9	6.6	4.6	1.4	0.24	1.0	33	80	38	59	2.6	30	
May 29, 1907.....	8:00 A.-11:30 P.	60	51	33	13.6	9.8	9.6	0.16	0.0	62	82	61	75	1.6	52	
Average	12:01 A.-11:30 P.	61	38	25	11.3	8.1	6.9	0.19	0.3	52	81	53	72	1.9	45	
Crude Sewage (High Level.)																
July 25, 1906.....	6:00 A.- 9:30 P.	61	19	11	5.0	1.8	6.4	0.45	0.0	26	20	15	14	0.2	11	
July 25-26, 1906..	9:30 P.- 5:30 A.	60	13	9	4.4	2.2	7.0	0.45	0.6	16	26	20	0.6	0.8	15	
Average	6:00 A.- 5:30 A.	61	17	10	4.8	1.9	6.6	0.45	0.2	23	22	17	1.1	0.4	12	

May 29, 1907.....	12:01 A.- 8:00 A.	52	13	9	7.0	5.0	5.0	0.36	2.0	24	22	7	36	5.8	22
May 29, 1907.....	8:00 A.-11:30 P.	54	37	26	11.6	8.3	12.4	0.20	0.0	42	64	53	69	1.8	39
Average	12:01 A.-11:30 P.	53	29	20	10.1	7.2	9.9	0.25	0.7	36	50	38	58	3.1	30
Crude Sewage (Average High and Low Level).															
July 25-26, 1906..	6:00 A.- 5:30 A.	62	20	13	5.1	2.1	6.7	0.46	0.2	24	34	27	19	0.6	17
May 29, 1907.....	12:01 A.-11:30 P.	58	37	25	11.5	7.6	7.8	0.20	0.4	49	74	55	68	2.3	43

TABLE NO. 60 — Concluded.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.												Remarks.
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	
					Organic.		Free Ammonia.	Nitrites.	Nitrates.							
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.				
							Septic Sewage.									
July 26-27, 1906..	9:30 A.-12:19 P. 11:20 P.- 2:43 A. 12:19 P.- 2:50 P.	66	13	....	5.6	2.8	7.6	.00	0.0	.....	30	19				Influent No. 1
July 26-27, 1906..	2:43 A.- 6:00 A. 2:50 P.- 5:42 P.	66	13	....	5.8	2.2	7.4	.00	0.0	.....	29	18				Influent No. 2
July 26-27, 1906..	6:00 A.- 9:10 A. 5:42 P.- 8:40 P.	66	17	....	5.2	1.6	8.0	.00	0.0	.....	35	29		1.4	....	Influent No. 3
July 26-27, 1906..	9:10 A.-11:10 A. 8:40 P.-11:20 P.	66	16	....	6.2	2.8	7.6	.00	0.0	.....	38	36				Influent No. 4
July 26-27, 1906..	11:10 A.- 1:53 P.	66	15	....	6.2	3.4	7.6	.00	0.0	.....	34	32				Influent No. 5
July 27-28, 1906..	2:30 P.- 2:30 A.	66	15	....	6.8	3.6	2.4	.00	0.0	.....	42	29	.....	0.4	.....	
May 29-30, 1907..	12:30 P.- 2:49 P. 12:03 A.- 2:40 A. 2:49 P.- 5:00 P.	55	28	....	15.0	....	9.0	0.12	.....	.....	85	43				Influent No. 1
May 29-30, 1907..	2:40 A.- 5:22 A. 5:00 P.- 7:24 P.	55	33	....	11.0	....	9.0	0.08	.....	.....	135	53				Influent No. 2
May 29-30, 1907..	5:22 A.- 8:02 A. 7:24 P.- 9:48 P.	55	33	....	6.0	....	10.0	0.01	.....	.....	93	50		2.5	....	Influent No. 3
May 29-30, 1907..	8:02 A.-10:24 A. 9:48 P.-12:03 A	55	35	....	14.0	....	10.0	0.01	.....	.....	135	53				Influent No. 4
May 29-30, 1907..	10:24 A.-12:13 P.	55	31	....	15.0	....	9.0	0.04	.....	.....	104	54				Influent No. 5

Average	May 29-30, 1907. 12:30 P.-12:31 P.	55	32	....	12.2	....	9.4	0.05	.....	.....	110	41	.....	2.5	.....	
							Effluent Contact Filters.									
July 26-27, 1906..	2:50 P.- 5:42 P. 6:30 A.- 9:10 A.	67	12.0	....	1.2	....	2.7	.04	2.8	.....	12	6			0	Filter No. 1
July 26-27, 1906..	5:42 P.- 8:15 P. 9:10 A.-11:10 A.	67	3.0	....	2.0	....	3.0	.04	1.6	.....	12	7			0	Filter No. 2
July 26-27, 1906..	8:15 P.-11:20 P. 11:10 A.- 1:53 P.	67	1.4	....	2.5	....	3.4	.03	2.0	.....	9	6		4.7	0	Filter No. 3
July 26-27, 1906..	11:20 P.- 2:40 A. 1:53 P.- 4:35 P.	67	5.3	....	1.5	....	2.0	.03	0.6	.....	10	5			0	Filter No. 4
July 27, 1906.....	2:40 A.- 6:00 A. 4:35 P.- 7:15 P.	67	3.8	....	1.9	....	7.0	.04	1.5	.....	11	6			0	Filter No. 5
July 27-28, 1906...	7:30 P.- 5:30 A.	67	9.0	....	2.5	....	.....	.00	0.0	.....	11	5	.....	4.0	0	Average
May 29-30, 1907..	5:00 P. 7:24 P. 5 22 A.- 8:02 A. 7:24 P.- 9:48 P.	55	9.4	....	1.1	....	3.7	.04	3.0	.....	40	25			0	Filter No. 3
May 29-30, 1907..	8:02 A.-10:24 A. 9:48 P.-12:03 A.	55	9.4	....	0.6	....	3.6	.03	1.4	.....	35	16			0	Filter No. 4
May 29-30, 1907..	10:24 A.-12:31 P.	55	9.4	....	0.4	....	3.6	.05	3.8	.....	39	20		2.5	0	Filter No. 5
May 30, 1907.....	12:03 A.- 2:40 A.	55	9.2	....	1.4	....	3.6	.05	1.6	.....	44	19			0	Filter No. 1
May 30, 1907.....	2:40 A.- 5:22 A.	55	8.7	....	0.4	....	3.6	.05	3.0	.....	40	26			0	Filter No. 2

MARION.

Marion is a city of about 19,000 inhabitants, acording to local records, and is in Marion County on the watershed of the Scioto River. The city drains into the Little Scioto River, which flows some three miles west of the thickly built up portion. Marion is a large industrial and railroad center, and is engaged in the manufacture of steam shovels, machinery and other similar products.

Municipal improvements have extensively been carried out. They include a public water supply, street paving, sanitary and storm sewers, and sewage purification and garbage disposal plants. The public water supply was installed in the year 1890, and is obtained from driven wells sunk from 100 to 200 feet in the chalk. According to the records of the water company, the daily consumption in the year 1906 was about 795,000 gallons, of which a small percentage is used by railroads and large manufacturing concerns.

SEWERAGE.

Sanitary sewers were first built about the year 1888. The sanitary sewage was conducted to a main outfall about two and one-half miles southwest of the city, where it was siphoned under Rock Swale Creek and finally discharged into the Little Scioto River. This system of disposal was in use until about December, 1905, when there was completed a plant to purify the sanitary sewage of the city.

As now existing, the sanitary sewers comprise about 25.3 miles of pipe sewers which range in size from 6 to 18 inches. The sewage is conducted to a purification plant about one mile northwest of the corporation line. The sanitary sewers are subdrained by about 40 miles of pipe sewers which range in size from 4 to 24 inches.

About 8,000 persons, or roughly 40 per cent of the present total population are connected to the sewers for sanitary purposes, according to information obtained from the city engineer. Practically no manufacturing wastes enter the sanitary sewers, although a number of the leading industrial establishments, public buildings and the like are connected to the sewers for sanitary purposes. These are listed as follows:

Iron mfg	4	Hotels	11
Saloons	32	Livery stables	16
School houses	10	Breweries	1
Churches	20	Dye works	4
Business blocks	32	Railroad stations	4

Strictly storm sewers comprise about 5.0 miles of sewers which range in size from 30-inch pipe sewers to 78-inch brick conduits. The storm sewer system has two outlets, one of which enters directly into Rock Swale Creek in the northern part of the city, the other in the southern section, discharges into the Little Scioto River.

The paved street mileage is about 22.7 and is brick, macadam, asphalt block and asphalt sheet. It is evident, therefore, that in the thickly built up portion, where practically all of the streets are paved, at times of heavy storms the run-off is considerable.

Marion. — General View of Plant. Garbage Crematory, Septic Tanks, Contact Filters and Sand Filters.

Marion. — Near View of Contact Filters, Showing Original Wooden Distributors.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

A few years after sanitary sewers were first built in Marion, such extremely foul conditions were created in the Little Scioto River for several miles below the sewer outlet, due to the discharge of unpurified sewage, that about the year 1900, agitation for an alleviation of this nuisance resulted in retaining engineers to make a report on the subject of sewage purification. Of wider scope, moreover, than the local nuisance at the point of discharge was the possibility of endangering the water supply of the city of Columbus. Plans for the purification of the sewage of Marion were forthwith prepared and were first presented to the State Board of Health in 1900. These plans were never carried out and the question of sewage purification was not again broached until 1904, when a second set of plans was presented. These new plans proposed a combined sewage purification and garbage disposal plant to be located about one mile northwest of the corporation line. After thoroughly reviewing the plans as presented, it was voted by the Board in October, 1904, to approve the same, calling attention to an agreement already made whereby samples of the filtering material used be submitted to and receive the approval of the State Board of Health before being used.

The plans as presented in the fall of 1904, provided for the purification of the sewage by preparatory treatment in grit chambers and septic tanks, followed by oxidation in contact filters and final treatment on sand filters operated at high rates. Adjacent to the septic tanks, there was planned a refuse incinerator or crematory inclosed in a two story brick building.

EXAMINATIONS AND INSPECTIONS.

Detailed examinations of this plant were made in 1906, on May 22-26, November 7-9, and in 1907 on April 9-11. Visits for inspection only occurred in 1907 on January 8th, March 7th, July 16th and November 2d. Several other visits were made in connection with investigations of the disinfection of sewage effluents.

DESCRIPTION OF PLANT.

The combined sewage purification and garbage plant of the city of Marion is located upon a 7-acre lot at the corner of Campbell and Gurley Pikes, about one mile northwest of the corporation line. The site is well chosen and is sufficiently removed from houses so that there is little possibility of odors causing a nuisance to those living near the plant and further because the haul for garbage is reasonable. The several features of the plant will be noted from the following description which is supplemented by Plates XXXIV. and XXXV.

Grit Chambers.

The crude unscreened sewage flows directly from the 18-inch main sewer into a grit chamber which extends the entire width of the three septic tanks. The chamber is 5 feet wide, 79 feet long and 5 feet 8 inches deep at the inlet end and extending 54 feet; the depth is then increased to 8 feet 5 inches for a distance of 25 feet. The walls are of concrete and are 2 feet thick; the bottom is of similar material and is 6 inches thick. The basin has a capacity of about 20,000 gallons. Flow through it is controlled by planks laid on the inlet weirs of the septic tanks. These planks serve as stop planks to arrest the flow into any one of the septic tanks.

Septic Tanks.

From the grit chambers the crude sewage flows into the septic tanks which are three in number and are constructed entirely of concrete with 24-inch walls and a six-inch base. The tanks are each 25 x 89 feet in plan and 10 feet deep and have a depth to the flow line of 8 feet 4 inches. Each tank has a capacity of 138,000 gallons and the total capacity of the system is 414,000 gallons. The three tanks are housed by a wooden pitched roof. A board walk is provided over the tanks and is hung on wooden stirrups. The tanks are accessible so far as relates to head room, but the pitched roof construction renders it difficult to reach the sides.

Inlets and Outlets. The sewage from the grit chambers enters the tanks by spilling over the full length of the 24-inch concrete wall between the grit chambers and the septic tanks. The loss of head by this method of inflow is about 6 inches. Sewage is discharged from the septic tanks over a weir which extends the full length of the end walls. From this point the sewage flows into a concrete channel which leads to the contact filters. It is also possible by means of stop planks to cause the sewage to pass through the 12-inch gates on one side of each tank and thus cause the sewage to enter all three tanks simultaneously but to discharge over the end wall of tank No. 1. This possibility of inlet flexibility may be noted from the drawings.

Baffles. One vertical baffle is provided, located across each tank 2 feet from the outlet end and extending 3 feet 5 inches below the flow line. This baffle is constructed of 2-inch lumber.

Sludge Drains. To provide for the removal of sludge from the septic tanks, at the outlet of tank No. 2 there is a 12-inch gate 12 inches from the bottom. This drain allows the removal of the supernatant sewage and lighter sludge until there remains about 12 inches depth of sewage in the tank. The drain passes under the contact filters to a manhole which leads to the creek. The floor of the tank is level and in the case of sludge disposal it would presumably be a question of pumping the lower foot at least.

Method of Control. There are no other means of controlling the flow to the three septic tanks other than loose 2-inch planks which are laid on top of the broad weirs at the inlets and outlets, respectively.

By-pass. A manhole some distance from the plant on the main sewer allows the by-passing of the septic tanks. It is also possible to by-pass the effluent from the septic tanks by a gate in the first gate chamber where are located the gates for controling the operation of the contact filters.

Aerating Chamber. Sewage from the septic tanks flows into a concrete chamber 80 feet long, 2 feet wide and 3 feet 6 inches deep. From this chamber outside the middle septic tank the main effluent carrier leads to the contact filters.

Measuring Weirs. There are no permanent means for measuring the discharge from the septic tanks, but during this special investigation, a wooden weir was placed at the outlet of tank No. 2. This weir can, of course, be used only when the entire discharge of sewage is taking place over the weir on tank No. 1.

Ventilation. To provide for the removal of obnoxious gases which might be formed in the septic tank house, the pitched roof covering the tanks is connected to the stack of the crematory.

Sludge Disposal Area.

No distinct area is set apart for disposing of sludge from the septic tanks. As originally planned, however, it was expected that from time to time sludge would be pumped from the septic tanks and be disposed of in the refuse incinerator. It was further expected that the deep section of the grit chamber would serve

Marion. — Near View of Contact Filters, Showing Grips.

Marion. — Contact Filters, Showing Construction of Under-drains.

also as a sort of collecting well, whence sludge from the septic tanks and from the shallower section of the grit chamber could be pumped to the combustion chamber of the garbage plant.

Contact Filters.

The effluent from the septic tanks is next treated in contact filters, which are six in number, each of which has an area of 4,000 square feet (48 x 83.5 feet), or a total area for the six units of 0.55 acre. The filters are situated on each side of a concrete dividing wall which separates the plant into two parts. They are contained in concrete basins with 12-inch dividing walls. The bottom of the filters is formed of clay puddle rolled to grade. The filters are uncovered.

Filtering Material. The filtering material is crushed limestone which had an original depth of 3 feet 3 inches and a depth over the underdraining tile of 2 feet 9 inches. The lower foot of the stone is of 2-inch size, while the upper layers are from ½ to 1½ inches. Some fine material and crusher dust is also present in the material as placed.

Underdrains. Each filter is underdrained by a main drain of 12-inch horseshoe tile which extends longitudinally through the filter and rests upon rolled clay puddle. Six lines of 6-inch tile enter the main drain at about 7-foot intervals. At the end of each lateral line, a 6-inch vitrified sewer pipe with screened top rises to the surface extending 10 inches above the filtering material.

Dosing and Distributing Devices. The operation of the plant is intended to be entirely by hand and hence its control in general is regulated by hand operated shear gates. There are no special arrangements for dosing the contact filters which receive the gravity flow of sewage from the septic tanks through an 18-inch vitrified pipe which leads from the aerating channel on the longitudinal center line of the plant. Two gate chambers 8 x 8 feet in plan, constructed of brick are located on the main dividing wall and contain gates for controlling the flow of sewage to and from the contact filters. The first gate chamber controls the operation of four contact filters, two on each side of the main dividing wall and the second controls the flow to the remaining two filters.

The distribution of sewage on the surface of the contact filters was originally effected by a system of branched wooden distributors. These were removed in the summer of 1907, and in their place there was constructed a shallow basin or "grip". This is practically a section of the filter set apart by a low bank of filtering material from 6 to 8 inches high upon which the entire flow of applied sewage is received. The banked-up filtering material is reinforced by a plank set vertically.

Effluent Discharge. The contact filters are discharged by the hand operation of gates in the gate chambers already described. The effluent flows from the filters directly onto the sand filters which are on an elevation lower by about 5 feet.

Sand Filters.

The effluent from the contact filters was planned to be treated on high rate sand filters in order to finish the purification and to render more certain the production of a satisfactory effluent. There are six filters and similarly to the contact filters they are divided into two sets of three by a main dividing wall which carries the 18-inch influent pipe. Each filter is 48 x 83.5 feet or 0.092 acre in area, and the total available area is 0.55 acre. They are contained in an excavation some 15 feet below the natural ground level and are separated by low 12-inch concrete walls. The bottoms of the filters consist of hard rolled clay puddle.

Filtering Material. While originally planned as sand filters, as the term

is usually understood, owing to the high cost and the difficulty of obtaining sand of the proper quality, permission was obtained from the State Board of Health to substitute for all but the upper 6 inches of sand a layer of fine limestone screenings which are practically comparable to fine gravel. The lower 2 feet of filtering material consists of from 6 to 8 inches of broken stone from ½ to 1½ inches in size and placed directly over the underdrains. The filtering material for the next 2 feet is limestone screenings which have an effective size of 0.80 m. m. and a uniformity coefficient of 6.0. Upon the screenings, sand is placed to a depth of from 2 to 5 inches varying in the six filters. The total depth of the filters is about 3 feet. The sand used has an effective size of 0.35 m. m. and a uniformity coefficient of 3.5.

Underdrains. The sand filters are underdrained similarly to the contact filters by a 12-inch main drain of horseshoe tile which extends longitudinally through each filter and rests on the rolled clay puddle. Four lateral lines of 6-inch tile are laid at right angles to the main drain. At the end of each lateral, for ventilating the underdrains, 6-inch vitrified sewer pipe extends to a height of 10 inches above the surface. The open end of the pipe is capped with wire gauze.

Dosing and Distributing Devices. The effluent from the contact filters flows by gravity through an 18-inch effluent pipe located in the central dividing wall. To operate the sand filters there are two gate chambers similar to those in use for the contact filters and similarly one controls the operation of four contact filters and one, two. Sewage is diverted to the filters by hand operated shear gates.

The distribution of sewage onto the sand filters is carried out by a system of branched wooden troughs unanchored. The main line extends longitudinally across the filters and is branched seven times. Hinged gates at the change of section of the distributors permit flexibility in the use of the several branches. There are no slabs nor other means to prevent undue disturbance of the surface sand.

Effluent Discharge. The effluent from the sand filters flows by gravity into an 18-inch vitrified sewer which leads to a concrete weir chamber. This is 12 feet 2 inches x 3 feet in plan and is 5 feet 6 inches deep at the forebay of a 3-foot non-contracted weir and is 7 feet 2 inches deep below this point. From this point, the effluent is conducted through about 1900 feet of vitrified pipe to Rock Swale Creek. A manhole is provided at the change of grade about 900 feet distant from the outlet weir chamber. The outlet is so situated that there is no danger from floods, although high water in Rock Swale Creek causes the effluent to back up in the outlet sewer for upwards of 1,000 feet.

SEWAGE FLOW.

The first two detailed examinations were made under strictly dry weather conditions. On the third, although there was no rainfall during the tests, yet considerable ground water was reaching the sewers owing to previous wet weather. The sewage flow at Marion has decidedly increased during this investigation. Maximum, minimum and average flows, respectively on the detailed examinations are shown in the following table.

TABLE NO. 61.

Volume of Sewage Flow on Detailed Examinations.

	Rate of Flow — Gallons in 24 Hours.		
	May 23–25, 1906.	Nov. 7-9, 1906.	Apr. 9-11, 1907.
Maximum	707,000	549,000	780,000
Minimum	220,000	137,000	430,000
Average	415,000	370,000	578,000

The corresponding average flow per persons tributary on the respective tests was 52, 46 and 72 gallons.

For eight months from June, 1906 to January, 1907, daily records were kept of the sewage flow at about 10 o'clock A. M. This information indicates the effect of storms and wet weather which largely increase the flow of sewage. The average flows by months computed from these records, show a range in flow in 24 hours from 254,000 to 895,000 gallons. The maximum flow observed was at the rate of 1,023,000 gallons. These monthly average flow records are shown in the following table.

TABLE NO. 62.

Sewage Flow by Months.

Date — 1906-07.	Rate in Gallons in 24 Hours.		
	Maximum.	Minimum.	Average.
June, 1906	907,000	302,000	405,000
July	488,000	165,000	364,000
August	526,000	179,000	325,000
September	397,000	178,000	309,000
October	565,000	178,000	254,000
November	975,000	204,000	473,000
December	953,000	565,000	744,000
January, 1907	1,023,000	772,000	895,000

Representative hourly variations in the sewage flow for a period of 24 hours are indicated by the data obtained on the test made April 9-11, 1907.

TABLE NO. 63.

Percentage Which Hourly Rate of Flow is of the Average.
April 10-11, 1907.

Hour.	Rate of flow Gal. in 24 hours.	Percentage of Average.	Hour.	Rate of flow Gal. in 24 hours.	Percentage of Average.
6:00 A. M.	450,000	78	6:00 P. M.	695,000	120
7:00 "	465,000	80	7:00 "	695,000	120
8:00 "	610,000	106	8:00 "	610,000	106
9:00 "	832,000	143	9:00 "	568,000	.98
10:00 "	740,000	128	10:00 "	550,000	95
11:00 "	788,000	136	11:00 "	490,000	85
12:00 "	788,000	136	12:00 "	465,000	80
1:00 P. M.	695,000	120	1:00 A. M.	465,000	80
2:00 "	740,000	128	2:00 "	390,000	68
3:00 "	740,000	128	3:00 "	390,000	68
4:00 "	740,000	128	4:00 "	390,000	68
5:00 "	720,000	125	5:00 "	450,000	78

COMPOSITION OF CRUDE SEWAGE.

The analytical evidence available from this investigation indicates that there are no distinctive features regarding the composition of the crude Marion sewage. The sewage is generally void of oxygen and is strictly a domestic sewage uninfluenced by manufacturing wastes. The unusual weakness of the night sewage as compared with that of the day is illustrated by the appended analytical data. Average results which are weighted analyses of the crude sewage collected on the three detailed examinations and which embrace 24 and 48-hour periods are as follows:

TABLE NO. 64.

Weighted Average Analyses of Crude Sewage.

Constituents—Parts Per Million.	Date of Examination.		
	May 23–25, 1906.*	Nov. 7-9, 1906.*	Apr. 9–10 1907.*
Temperature, degrees F.	59	59	52
Oxygen Consumed—			
Total	61	59	32
Dissolved	37	24	24
Nitrogen, organic—			
Total	45.0	17.9	16.2
Dissolved	20.0	5.1	9.8
Free Ammonia	18.5	20.7	15.5
Nitrites	0.00	0.00	0.08
Nitrates	0.0	0.0	0.0

TABLE NO. 64 — Concluded.

Constituents—Parts Per Million.	Date of Examination.		
	May 23–25, 1906.*	Nov. 7-9, 1906.*	Apr. 9–10 1907.*
Chlorine	79	25	49
Suspended Matter—			
Total	154	90	43
Volatile	72	58	25
Free Carbonic Acid	29	48	27
Dissolved Oxygen	0.0	0.0	0.2
Fats	53	26	62

* Forty-eight hours.

OPERATION.

The Marion sewage purification and garbage disposal plant is under the direction of the board of public service, and is under the direct supervision of the city engineer. The plant was first placed in operation in December, 1905, and at that time and until the summer of 1906 two men were employed in its operation on day and night shifts, respectively. After the summer of 1906 and continuing throughout this investigation, no garbage was received after nightfall and the night man was dismissed. An assistant superintendent was then appointed for service in the day time. In addition to the above, from time to time, other labor has been employed for cleaning the filters. No pumping is, of course, carried out at the plant and the operation of the sewage purification devices relate to the opening and closing of the hand operated valves which control the contact filters and the sand filters, together with other duties incidental to the operation of the grit chambers and septic tanks.

For the purposes of this investigation from June, 1906, to July, 1907, daily records were kept by the superintendent of the plant of certain features of its operation. These included weir measurements, temperature observations, notes as to the operation of the septic tanks and contact filters and putrescibility tests on the effluents of the contact filters and the high rate sand filters.

Grit Chambers and Septic Tanks.

The layout of the grit chambers and septic tanks, of course, suggests that the grit chamber in service depends upon the operation of the septic tanks. The septic tanks in use at one time have varied greatly during the investigation. Up to June, 1907, practically one tank only was in service, but after that time all three tanks have been used. There was no regularity in this regard, but the tanks were changed frequently in an attempt to obtain a better clarified septic effluent. During the first year the plant was operated, tank No. 3 was in service for 116 days, that is from December 4, 1905, to April 1, 1906. It was followed by tank No. 2 for 79 days, tank No. 1 for 56 days and tank No. 2 again for 25 days, following which the tanks were generally alternated at weekly intervals until all three were used at the same time as above stated. During the year 1906, and part of the year 1907, sewage was caused to flow over the outlet weir of the tank in service. Since the summer of 1907, however, when all three tanks had been used, sewage has been allowed to flow longitudinally through the three

tanks, across the end of No. 3 through the 12-inch pipe in the dividing wall into tank No. 2 and similarly from tank No. 2 into tank No. 1, so that the total flow of sewage has passed from the three septic tanks over the outlet weir of one tank.

Based on an average sewage flow of 650,000 gallons with one tank in service, the period of flow is about 5 hours; with three tanks in service 15 hours, as now prevails. The corresponding linear velocities are 0.49 and 1.47 m. m. per second.

Sludge Disposal. No sludge has been removed from the septic tanks since the plant was first placed in service, and according to measurements made during this investigation there has been but a slight accumulation of sludge. The grit chambers intercept considerable putrescible matter which due to active gas formation from time to time rises to the surface and tends to block the channel. It is customary to force this erupted sludge into the septic tanks for which purpose a wooden shovel has been used. Another feature developed in the operation of the grit chambers, namely, the collection of fatty matters at the entrance to the septic tanks. Recently, it has been the practice to remove these floating matters with a wire gauze skimmer.

Deterioration of Iron Sheathing. When the plant was built, a galvanized iron imitation brick sheathing was used on the sides of the structure enclosing the septic tanks. After about six months, the gases in and about the septic tanks combined with moisture practically entirely destroyed the sheathing so that it crumbled when touched. The building was subsequently resheathed with wood. The decay of this iron sheathing by moisture and gases indicates strongly that this material cannot be properly used in a sewage plant.

Repairing of Walks. The passage way over the septic tanks originally comprised wooden hangers which were fastened with nails and were so arranged that the lower part was beneath the surface of the sewage. After about eight months, the iron nails rusted and it was necessary to reconstruct the walk. The new walk was fastened with bolts, provided with a hand railing and placed at an elevation above that of the sewage in the tanks. At this time all the wood work in the septic tanks was whitewashed.

Contact Filters.

The contact filters at Marion are entirely hand operated. Ordinarily, one side of the plant comprising three units is in service for a period of one week.

Day Operation. During this investigation in the day time from about 7:00 o'clock A. M. until 5:00 o'clock P. M. the contact filters are operated on the fill-and-draw plan and are filled in turn. The first filter flooded is held full until the second is filled. The different conditions of the filters are as follows: one is being flooded; one is held full; and one is discharging.

Night Operation. When a night man was employed in the operation of the garbage disposal plant, after 5:00 o'clock P. M. it was the practice to allow the septic effluent to flow onto one or two contact filters depending upon weather conditions. The outlets were closed and the capacity of the filters used was sufficient to receive the entire night sewage flow. When the night man was dismissed in June, 1906, the night operation of the contact filters was decidedly changed. During dry weather it is the practice to allow the septic effluent to flow onto one of the contact filters, the outlet valve of which is wide open. The sewage thus passes downward continuously. During stormy weather, or whenever an unusually high sewage flow is expected, two contact filters are thus operated.

Length of Cycles. The period of filling has varied from one hour to one

and three-fourths hours, and at times of especially high flow has been less than one hour. The period of standing full has varied correspondingly. The resting period during operation generally ranges from 2 to 3 hours. Normally, of course, one side of the plant is rested for one full week. On the three detailed examinations, during the day hours, from 6 to 9 filters have been used. In very wet weather at times 12 filters are necessary during the day operation. Based on the average sewage flow at Marion of about 650,000 gallons in 24 hours, the contact filters for the usual day period of 10 hours, have been operated at an actual rate of 1,180,000 gallons in 24 hours and at an average rate of practically one-half this amount. The area of contact filters corresponds to 14,500 persons per acre, or 5,250 persons per acre-foot.

Cleaning and Gripping. Due to the large quantities of suspended matter contained in the applied septic sewage, the surfaces of the contact filters have been greatly clogged practically throughout this investigation. After the first ten months' operation, on September 24th, 1906, and continuing for two weeks, two men working eight hours daily, assisted in part by the superintendent, were engaged in cleaning the contact filters. The deposit was about 3 inches in average depth, although pockets were found at a greater depth. The filters were first allowed to rest for one week after which the deposits tended to curl up and could readily be removed with a fork. (Available flow data are not sufficiently precise to enable the quantity of material removed to be expressed in terms of the total volume of sewage treated for this period.)

Serious clogging was again noted on the examination made two months later on November 7-9, 1906, and at this time the superintendent of the plant suggested the removal of the wooden distributors and the construction of shallow settling basins or grips, to which the sewage would be applied with the idea that the suspended matter could in a large part be confined to a comparatively small area, a measure which would greatly facilitate cleaning. On February 15, 1907, one of the contact filters was very badly clogged and it was necessary to remove the clogged material. The feature of gripping was then tried with this filter and was effected by constructing a shallow basin about 5 feet wide, extending longitudinally across the filter on the side adjacent to the influent inlet. The concrete dividing wall formed one side of the basin, and fine crushed stone reinforced with plank, heaped up to a height of perhaps 6 inches, formed the other. Practically for one month, February 15th to March 15th, 1907, two men were engaged in cleaning the filters. The deposit ranged in depth from ½ to 2 inches. Perhaps 2 inches of the filtering material were also removed, as the deposit was so intimately mixed with the broken stone that a clean separation was not possible. It was stated that two men with wheelbarrows required two days to clean one of the 0.09-acre units.

Filter No. 1 which had been "gripped" indicated that the substitution of a grip for the wooden carrier was a decided improvement in that it minimized labor in cleaning the filters. Consequently, from July 1st to 20th, 1907, when all the contact filters were again cleaned, grips were placed on all of them. In regard to the operation of the grips, they were first cleaned after two weeks' service, later, and as has prevailed since the summer of 1907, they are cleaned after each week's run, after allowing sufficient time for the sludge to dry. The grips serve admirably to protect the main body of the filtering material, and it is noticeable that the greater part of the suspended matter in the applied sewage is thus retained. After the initial application of sewage to a grip which has just been cleaned, rapid clogging ensues and thereby forms practically an impervious basin over the side of which the sewage flows in a thin sheet. Later information in this regard obtained on the final inspection is to the effect that after operation for one week, from 4 to 5 cubic yards of sludge are stated to

be removed. Based upon the average sewage flow and taking into consideration the limited time the contact filters are used daily, this quantity of sludge corresponds to the high figure of from 4 to 7 cubic yards per million gallons. It is to be noted that the quantity of suspended matter discharged from the septic tanks, as will be presently discussed, varies within wide limits and depends somewhat on weather conditons, and it is probable that the above figures are high for average conditions.

Holding Capacity. The extensive clogging of the contact filters naturally suggests a reduction in capacity. On each of the detailed examinations, observations have been made to indicate the quantity of sewage contained in the pores of the filtering material at each contact. The data available in this regard show a certain reduction in capacity during the past two years, but on account of the hand operation of the plant, and the personal equation incidental to the diversion of the sewage to the several filters, the data are not strictly accurate. They are, however, suggestive that the penetration of sludge has not been very great. Representative data as to the holding capacity of the six contact filters are as follows:

TABLE NO. 65.

Capacities of Marion Contact Filters.

Filter Nos.	Holding Capacity. Gallons.		
	May 26, 1906.	Nov. 9, 1906.	April 9, 1907.
1	28,000	31,000	.....
2	26,000	.....	29,000
3	30,000	24,000	.....
4	26,000	21,000	31,000
5	30,000	30,000	.....
6	30,000	.....	29,000

Trapped Outlets. It was learned at the first detailed examination that the outlets of the filters were so placed as to be trapped, that is, water always stands in the underdrains to a depth of 6 inches. It is obvious that this feature precludes any ventilation effect, which might accrue from the original provision of direct connection between the aerating pipes and the chimney in the crematory.

Leakage into Drain from Septic Tanks. It developed during this investigation that there exists considerable leakage from the contact filters on the south side of the plant into the drain from the septic tanks. During construction it is stated that poor joints were made in this drain and that they were not properly cemented before construction was completed. This feature causes a slight lowering in the south filters during the standing-full period.

Sand Filters.

When first operated, three sand filters were used on alternate days. After six weeks there was a slight coating on the surface of the sand, which was also slightly compacted. It was then the practice to loosen the sand once a month with a short toothed rake. The filters were never operated as water filters, that

is, with submerged surfaces, in view of the fact that the wooden distributors were not anchored. The above original method of operation included the use of the sand filters at night.

Following the summer of 1906, three sand filters have been used daily and those on the other side of the central dividing wall have been used on alternate weeks. It was first attempted to use the sand filters at night when the contact filters were being flooded continuously, but such marked discoloration and such serious clogging ensued that the practice was discontinued and with the exception of the few days on which detailed examinations have been made during this investigation, the daily period of service of the sand filters has been from 10:00 o'clock A. M. until 5:00 o'clock P. M. Before and after these hours, the contact filter effluent has been discharged directly into the effluent sewer.

The distribution afforded by the branched wooden troughs, when receiving the direct gravity flow from the contact filters, has been such as to wet only about 60 per cent. of the available area. It has been the practice lightly to rake the sand about three days after a week's period of service. In the summer of 1907, all the filters were spaded to the surface of the supporting limestone, and were raked three times to remove weeds. Very little sludge has formed on the sand, but at times a slight algal growth, found during this investigation to be *Spirogyra* has been noted and in some places a slight coating of moss. No sand has been removed since the plant was first operated. In view of the fact that the sand is thin in some instances, it is strongly advisable that the filters be resanded to the original specified depth of 6 inches.

The average rate of operation is about 590,000 gallons and the actual rate 1,180,000 gallons in 24 hours for a period of seven hours. The available area of these filters corresponds to 14,500 persons per acre.

By-passing of Plant.

Except during a few heavy storms, the crude and septic sewage has at all times been purified in part at least by treatment on the contact filters. During the experimental work in connection with the disinfection of sewage effluents, septic sewage without further treatment was by-passed into the effluent sewer. Normally, the operation of the plant is faithfully carried out.

As before stated, daily temperature records have been kept by the superintendent. Average results by months, from June, 1906, to March, 1907, inclusive, are shown in the following table. It is of interest to note the changes in temperature of the sewage in passing through the plant with relation to the average temperature of the air.

TABLE NO. 66.

Average Temperature.

June, 1906, to March, 1907, Inclusive.

Months.	Temperature. Degrees F.				
	Air.	Sewage.	Outlet of Septic Tanks.	Outlet of Contact Filters.	Outlet of Sand Filters.
1906.					
June	76	62	62	64	67
July	76	64	64	68	71
August	83	68	68	72	76
September	83	67	67	70	72
October	62	62	62	61	60
November	46	57	57	55	51
December	36	53	53	50	46
1907.					
January	35	51	51	47	45
February	34	51	50	43	40
March	54	50	50	49	48

EFFICIENCY.

The character of the purification of the Marion sewage effected by the plant has been judged from inspections and directly from the analytical data obtained during this investigation. The method of collecting samples of the several sewages is somewhat distinctive and will be stated here for the sake of clearness.

Collection of Samples for Analysis.

Samples of the crude sewage were collected in bottles at half hourly intervals and in accordance with the general scheme of sampling were mixed to form an average, corresponding to the day and night sewage in proportion to the sewage flow as shown by weir measurements.

Samples of the effluent from the septic tanks were collected in equal portions at half hourly intervals following six hours after the collection of the crude sewage samples. The period of sampling was continued correspondingly six hours after the sampling of the crude sewage had ceased. On certain occasions also, samples of the septic sewage were collected to correspond to the average influent to the several contact filters.

At five minute intervals during the discharge of a contact filter, equal portions of the effluent were collected to form an average sample for a period of from 40 minutes to one hour. On some tests the effluents from the filters were individualized and in other cases the average effluents for a day were mixed to form a composite. The night effluents from the contact filters were collected in equal portions at half hourly intervals. Samples of the sand filter effluents were collected at half hourly intervals in bottles and were mixed in proportion to the rate of flow. The night samples, which were similarly collected, were

separately averaged for analysis. Details as to the method of sampling on the different examinations will be clear from the appended analytical data.

Screening.

The crude sewage of Marion flows into the grit chambers and septic tanks without screening. When the plant was first operated a screen composed of 1-inch mesh wire screening was in use, but clogged so rapidly and was so difficult to clean, that its use was abandoned in the spring of 1906. It was recommended during this investigation to provide a suitable screen, but nothing was done in the matter.

Grit Chambers.

The grit chambers have at all times intercepted large quantities of suspended matter, due to the somewhat low velocity of flow in the tanks. In the early part of the work it was strikingly noticeable that the material intercepted was not of a mineral nature, but was organic in character and readily decomposed.

The quantity of sludge deposited in the grit chambers has varied widely. The deposit has generally extended only for the first 50 feet and from the inlet to this point has ranged in depth from 4 feet 6 inches to 6 inches. The deposition has been particularly heavy opposite the inlet of septic tank No. 3, or that nearest the inlet of raw sewage. The putrescible character of the sludge is such that the rapidly forming gases of decomposition cause sudden upheavals, which necessitate shoveling the floating material into the septic tanks, as already mentioned. The general character of the sludge is shown by the analytical data presented below. The fact that practically but little mineral matter has been intercepted by the grit chambers, and that they have caused the deposition of large quantities of putrescible matters, suggests that for Marion conditions, at least, grit chambers are not a necessary adjunct to the preparatory devices.

Septic Tanks.

The clogging of the contact filters previously discussed, suggests that the septic tanks ordinarily have not afforded an efficient clarification or preparatory treatment of the sewage. Analytical data available from the three detailed examinations, together with observations made on the several visits to the plant, have shown that the greater part of the suspended matters in the crude sewage have passed out of the tanks, generally at those periods when due in part to temperature changes and in part to the development of gases in the sludge deposits, masses of sludge have been forcibly carried to the surface of the sewage and have not subsided with sufficient rapidity again to fall to the bottom of the tanks before the sewage reaches the outlet. The variable removal of suspended matter afforded by the tanks is illustrated by representative data in this regard obtained on the detailed examination of November 8-9, 1906. The crude sewage on this test averaged 90 parts per million of suspended matter, and the effluent contained from 100 to 228 parts per million and in general was higher in suspended matter than the crude sewage.

On practically all of the visits, the effluent from the septic tanks has been very black in color due to the finely divided suspended matters. According to the superintendent of the plant, the discharge of sludge from the septic tanks with the effluent is most marked in the spring and fall, a fact which suggests that possibly the spring and fall overturn is one of the chief causes. From considerations relative to the point of decomposition of the sludge in the tanks, as will be presently discussed, it seems to be clear that in the absence of a central transverse baffle, some of the putrescible suspended matters are deposited at a point in the tanks with relation to the outlet, such that when they are set in motion

by the rising gas, the path of travel is so short that no opportunity is afforded for the resubsidence of the sludge and consequently the suspended matters are carried out with the effluent. At all times very violent action has been noted in the sludge. From time to time, the operation of the septic tanks has been varied with a view to obtaining a higher efficiency. On the basis of an average sewage flow of 650,000 gallons in 24 hours, with one tank in service, the period of flow is 5 hours, and the velocity is 1.48 m. m. per second or 17.8 feet per hour. With three tanks in service these figures are 15 hours, 0.49 m. m. per second, and 5 feet per hour, respectively. Table No. 67 shows the suspended matters in the samples of the septic effluent collected during the examination of November 7-9, 1906. During this examination the fermentation in the septic tanks was very active, a fact which probably accounts for the presence of such large quantities of suspended matter in the septic tank effluent.

TABLE NO. 67.

Suspended Matter in the Crude Sewage and in the Effluent of the Septic Tanks on November 8-9, 1906.

Source.	Hour.	Suspended Matter.	
		Total.	Volatile.
Crude Sewage	12:01 A. M.—8:00 A. M..... Nov. 8, '06.	115	86
	8:30 A. M.—11:30 P. M.... Nov. 8, '06.	85	52
	Weighted Average	95	63
Crude Sewage	12:01 A. M.—8:00 A. M..... Nov. 9, '06.	59	32
	8:00 A. M.—11:30 P. M.....	99	62
	Weighted Average	86	53
	Nov. 8, '06.		
Influent Contact Filter No. 1.....	5:00 A. M.—7.40 A. M.....	159	75
Influent Contact Filter No. 3.....	7.40 A. M.—9:15 A. M.....	152	74
Influent Contact Filter No. 5.....	9:15 A. M.—10:00 A. M.....	145	75
Influent Contact Filter No. 1.....	10.40 A. M.—12:00 Noon...		
	2:40 P. M.— 4:00 P. M...	202	107
Influent Contact Filter No. 3.....	12:00 Noon—1:20 P. M.....		
	4:00 P. M.—5:20 P. M.....	228	135
Influent Contact Filter No. 5.....	1:20 P. M.—2:40 P. M.....	168	98
	Nov. 8-9, '06.		
Average Influent	4:40 P. M.—6:00 A. M.....	120	89
	Nov. 9, '06.		
Average Influent	8:45 A. M.—4:45 P. M.....	100	66

Scum Formation. Scum is formed at Marion only on tank No. 3. After about four months of operation, the scum on this tank was from 9 to 16 inches in thickness. It gradually decreased and about nine months later was only from 3 to 4 inches in thickness. The tank was put in service during the rainy weather of the winter of 1906, and on the visit of January 8, 1907, the scum had practically disappeared. Some scum has always been noted on this tank and in the following April was perhaps from 1 to 6 inches in thickness.

The absence of scum in the other two tanks suggests that the third tank receives more of the lighter putrescible matters of the crude sewage. This tank is nearest to the inlet of raw sewage, and, of course, receives sewage which has received the least preliminary sedimentation in the grit chambers. In the case of tanks Nos. 1 and 2, the coarser putrescible matters have been more or less broken up by bacterial action, as already related and when they finally enter the septic tanks in the process of cleaning the grit chambers, they are of such a character that they do not form a permanent scum.

Sludge Accumulation. The accumulation of sludge has been very variable. On the first detailed examination when one tank was in service, it is estimated that the quantity of sludge was about 21 cubic yards. Rough measurements at 15-foot intervals from the inlet indicated the range in depth to be from 15 inches at the inlet to 3 to 4 inches at the outlet. Fifteen feet from the inlet the sludge deposit was 9 inches thick. On subsequent visits, ordinarily very little sludge was noticed in the tanks. This feature is also suggested by the serious clogging of the surface of the contact filters.

Composition of Sludge. On the examination of May 25, 1906, samples of the sludge were collected at 15-foot intervals from one of the septic tanks, and also from the grit chambers together with a sample of scum from septic tank No. 3. It was attempted to measure the sludge with a Fowler sludge tube, but the deposit was so heavy that it was not found possible to adopt this method. In subsequent work consequently, measurements were made with a pole. The analyses of the sludge samples collected on this examination are shown in the following table. After the first 15 feet there appears to be little change in the composition of the sludge. These analyses are also instructive as indicating the putrescible character of the material intercepted in the grit chambers, and as suggesting the relatively large percentage of nitrogen, volatile matters and fats present in the scum.

TABLE NO. 68.

Analyses of Scum and Sludge, May 25, 1906.

Source.	Distance from Inlet (feet).	Percentage by Weight.				
		Volatile.	Nitrogen.	FeS.	Fe.	Fats.
Scum	.....	9.55	0.47	0.21	1.22	3.60
Grit Chamber	.....	3.80	0.14	0.23	0.42	1.43
Septic Tank	0	4.30	0.18	0.19	0.38	1.95
" "	15	3.50	0.14	0.21	0.50	1.31
" "	30	3.50	0.13	0.22	0.36	1.08
" "	45	3.10	0.15	0.21	0.42	1.15
" "	60	3.20	0.15	0.21	0.54	1.38
" "	75	3.30	0.16	0.18	0.60	1.21

NOTE — All determinations except Ferrous sulphide (FeS) on dry sludge.

Odors and Ventilation. On the examination in May, 1906, considerable odor was noted around the septic tanks. It was apparent that very little benefit was accruing from the feature of a connection between the septic tank house and the chimney of the crematory. Subsequently, windows were placed in the septic tank house and the door was generally opened with a result that the ventilation was much improved and objectionable odors were less apparent. With reference to odors from these tanks it is of interest to note that the condition of the atmosphere is a large determining factor. On clear days with light air, odors are not particularly in evidence, but on heavy muggy days a decided odor has been apparent near the septic tanks.

Dissolved Oxygen. As has been stated, the crude Marion sewage rarely contains dissolved oxygen and none was found in the effluent from the septic tanks during this investigation.

Contact Filters. The analysis of samples of the contact filter effluent collected on the examinations of the plant, together with daily putrescibility tests made at the plant for a period of 13 months, have shown that the contact filters are usually putrescible and that during the night period of continuous operation the degree of purification is decidedly less than obtains when the filters are operated strictly on the fill-and-draw basis. Analytical evidence indicates that the effluents are rarely oxygenated, and that except after a period of rest usually do not contain nitrates. Ordinarily, the effluents are low in suspended matter. Average data in this regard indicate that they contain about 33 parts per million or 0.14 ton dry suspended matter per million gallons. Odor from the contact filters is slight, but as perhaps is to be expected, considerable odor arises from the sludge on the contact filters especially when it is exposed during cleaning.

Day and Night Effluents Compared. On the second detailed examination, interesting data were obtained relative to the efficiency of the contact filters during the day and night operations, respectively. These results are presented beyond in Table No. 70, in discussing the efficiency of the sand filters. The chief change noticeable is the decided increase in nitrogen as free ammonia and the entire absence of nitrates. These are average data for the two periods specified.

Nitrification After a Period of Rest. Of theoretical interest regarding the efficiency of the contact filters are data collected during this investigation relative to the nitrates in the Marion contact filters on the first discharge after a resting period of one week. These data which are shown below suggest clearly that during the resting period quantities of nitrates are formed, which are washed out of the filter when it is discharged after the initial flooding. The quantity of nitrates as shown below is, of course, very high for a filter of this type and no doubt was amply sufficient to protect the effluent from putrefactive decomposition. The deterioration in the effluent on subsequent contacts is also clearly indicated.

TABLE NO. 69.

Comparison of Effluents of Contact Filters During First Discharge After a Period of Rest and After the Resumption of Normal Operation on November 7-9, 1906.

Constituents.	Parts Per Million.					
	*First Contact. Filter No.			†Subsequent Contacts. Filter No.		
	1	3	5	1	3	5
Oxygen consumed	17.	22.	15.	23.	33.	23.
Nitrogen as—						
Organic	8.8	8.6	8.8	9.8	8.2	7.8
Free Ammonia	15.0	12.0	11.0	17.2	12.4	12.0
Nitrites	.20	.15	.10	.08	.12	.02
Nitrates	7.6	8.0	11.0	0.6	3.0	6.0
Suspended Matter	47.	60.	52.	55.	58.	48.
Dissolved Oxygen	0.0	0.0	0.6	0.0	0.0	0.0
Putrescibility	0.	0.	0.	+	0.	+

* Rest of one week.

† Average of two contacts Filter Nos. 1 and 3.

† Average of one contact Filter No. 5.

Sand Filters.

All the evidence obtained during this investigation by daily putrescibility tests and from analyses, indicates that the sand filters purify the putrescible contact filter effluents to the non-putrescible stage. As appended detailed analytical data indicate, the effluent from the sand filters at this plant is generally well oxygenated, contains considerable nitrified nitrogen and is ordinarily low in suspended matter. Regarding the bacterial contact of both the sand filter effluents and the contact filter effluents, considerable information is contained in the special discussion of the disinfection of sewage effluents which follows this report. Practically none of the daily putrescibility tests which cover 13 months, indicated a putrescible effluent by the odor test, and on only about five occasions did the chemical test show positive results, that is, an exhaustion of the oxygen in the sample and aerated tap water.

It has been stated that ordinarily during this investigation, the sand filters have been operated for only about 8 hours daily, but that on the three detailed examinations they have been flooded for the full 24 hours. During the night hours on the three examinations, the sand filters, of course, received the least highly purified contact filter effluent and they showed a corresponding decrease in efficiency. Suggestive data as to the desirability of a well purified effluent as an influent to high rate sand filters. are representative results obtained on the examination of November 7-9, 1906. The distinct relation between the character of the applied sewage and that of the effluent is strongly suggested. In both instances it will be noted that the effluent was non-putrescible, although it contained no dissolved oxygen.

TABLE NO. 70.

Comparative Efficiencies of Day and Night Operation of Contact Filters and Sand Filters.

November 7-8, 1906.	Parts Per Million.					
	Septic Sewage.		Contact Filters.		Sand Filters.	
	Day.	Night.	Day.	Night.	Day.	Night.
Oxygen Consumed	71	62	26	22	18	14
Nitrogen as —						
Organic	22.3	20.6	8.6	7.8	7.4	9.8
Free Ammonia	23.1	27.0	13.9	24.0	7.0	10.4
Nitrites	0.00	0.00	.07	.03	.12	.14
Nitrates	0.0	0.0	3.2	0.0	12.0	6.8
Suspended Matter	176	120	54	38	40	26
Dissolved Oxygen	0	0	0.0	0.0	0.7	0.0
Putrescibility	+	+	+	+	0	0

Collection of Samples.

Septic Sewage. — Day, 5:00 a. m. to 2:40 p. m. Night, 4:40 p. m. to 6:00 a. m.

Contact Filters — Day, 9:15 a. m. to 4:40 p. m. Night, 4:40 p. m. to 6:00 a. m.

Sand Filters — Day, 10:30 a. m. to 5:30 p. m. Night, 6:00 p. m. to 6:00 a. m.

SUMMARY.

The results of this examination have shown that the general efficiency of the Marion plant is excellent. Under the present method of operation without a night attendant, a putrescible effluent is discharged into Rock Swale Creek. It is probable, however, that the dilution there afforded is sufficient to overcome objectionable conditions.

The Marion plant has been well operated and it is especially to be remarked that the officials have taken a decided interest in this special investigation and have co-operated in every way with the State Board of Health.

Certain features of the plant, notably the preparatory devices, have not been efficient. The grit chambers have intercepted large quantities of putrescible matters, and in view of local conditions, this investigation has shown that they are not necessary and in fact are a decided disadvantage. The suspended matters deposited in the septic tanks at all times have been such as to be readily attacked by bacteria, the constant formation of gas and an upward and downward movement of sludge has been especially marked. The evidence is strong that an efficient screen should be provided to intercept the coarser matters of the crude sewage. With a view to improving the efficiency of the septic tanks it is recommended that they should be baffled with a submerged transverse baffle located about two-thirds of the distance from the inlet to the outlet. Owing to the frequent and general passage of sludge out of the tanks, it has not been neces-

sary to clean them, and furthermore, no attempts have been made to cremate sludge from the grit chambers or the septic tanks.

The removal of the wooden distributor from the contact filters and the substitution of shallow settling basins or grips, has decidedly improved the operation of the contact filters, and Marion experiences in this regard suggest that a thorough distribution of sewage on contact filters is not necessary, and further that unless the preparatory treatment is especially thorough, much better results can be obtained if the sewage is caused to flow onto a limited area only.

The contact filters have not purified the sewage to the non-putrescible state, but when operated, the finishing high rate sand filters have at all times accomplished this result. The success of these sand filters which contain only a few inches of sand supported by crushed limestone screenings is of special interest as showing a means for economy in the first cost of subsidiary filters. The results from this investigation, however, have strongly indicated that the sewage applied to the subsidiary filters should be as highly purified as possible, as otherwise rapid clogging will ensue in the high rate sand filters. In considering the work of the sand filters, and the fact that it has not been necessary to remove sand, it is especially to be noted that the filters have been operated for only about eight hours daily. As there is probably too small a depth of actual sand on these high rate filters, it is suggested that they be filled to original grades with a proper quality of lake or bank sand.

As a further improvement to the Marion plant, it is also strongly recommended that a night attendant be again employed, that the operation of the contact filters may again be normal, that a non-putrescible effluent may be discharged from the plant at all times during the day and night. The plant was designed for a capacity of 600,000 gallons. Since first studies were made regarding the problem at Marion, the sewage flow has largely increased and at the end of this investigation, the capacity of the plant had almost been reached. Aside from difficulties attending the clogging of the contact filters, there appears to be no serious difficulty in operating the plant, and the resulting effluent is generally satisfactory, except as previously noted. A large increase in the population of the city or the construction of new sewers will no doubt necessitate an enlargement of the plant, a necessity which probably will develop in the not far distant future.

COSTS.

The total cost of the Marion sewage purification plant including land. septic tanks, contact filters and sand filters was $45,500. The contact filters cost $13,000, or at the rate of $23,600 per acre. The sand filters similarly cost $36,000 per acre. In regard to these high costs, it is to be stated that the filters are from 10 to 15 feet below the general ground level and that the excavation was in hard blue clay. In the case of the sand filters some of the excavation is stated to have cost from $3.00 to $4.00 per cubic yard. The itemized cost of constructing the plant is as follows:

Land	$2,500
Septic tanks	10,000
Contact filters	13,000
Sand filters	20,000
	$45,500

The operating costs of the plant for the year 1906 were $1,033.68, and for 1907, $1.223.84. On the basis of 8,000 persons tributary to the plant these figures amount to 13 cents and 15 cents per capita per annum for the above years.

TABLE NO. 71.

Operating Costs.

Year.	1906.	1907.
One-half Superintendent's salary	$450 00	$450 00
Assistant Superintendent's salary	*60 00	360 00
Extra labor	227 33	122 45
Supplies	235 35	236 34
Stone for road	40 50	55 05
Livery	20 50	.....
Total	$1,033 68	$1,223 84

* Two months.

TABLE NO. 72.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.														Remarks.
			Oxygen Consum'd.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.	
			Total.	Dissolved.	Organic. Total.	Organic. Dissolved.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Volatile.					
						Crude Sewage.											
May 24, 1906...	12:01 A.- 11:30 A....	53	78	39	45.0	29.2	18.0	0.00	0.0	53	190	106	34	0.0	.....	25	Dissolved oxygen av. of 13 detrm'ns
May 24, 1906.....	12:00 Noon-12:00 P....	50	48	38	37.0	26.8	19.5	0.00	0.0	94	133	62	34	0.0	.....	46	
Weighted Av'ge.		52	63	38	41.0	28.0	18.8	0.00	0.0	74	162	84	34	0.0	.....	36	
May 24-25, 1906..	12:00 Md.- 12:00 Noon.	47	66	40	67.0	12.3	17.5	0.00	0.0	65	109	36	24	0.0	.....	65	
May 25, 1906.....	12:00 Noon-12:00 Md..	..	53	32	32.4	12.1	19.0	0.00	0.0	102	180	85	26	0.0	.....	74	
Weighted Av'ge.		..	60	36	49.7	12.2	18.3	0.00	0.0	94	145	61	25	0.0	.....	70	
Average	May 23-25, 1906.	..	61	37	45.0	20.0	18.5	0.00	0.0	79	154	72	29	0.0	.....	53	
Nov. 8, 1906.....	12:01 A.- 8:00 A.....	59	43	31	22.8	5.4	20.0	0.00	0.0	12	115	86	55	0.0	.....	26	Dissolved oxygen av. of 12 detrm'ns
Nov. 8, 1906.....	8:30 A.- 11:30 P.....	58	84	23	19.0	5.6	19.0	0.00	0.0	29	85	52	49	0.0	.....	27	
Weighted Av'ge.		58	70	26	20.3	5.5	19.0	0.00	0.0	23	95	63	51	0.0	.....	27	

TABLE NO. 72 — Continued.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.														Remarks.
			Oxygen Consumd.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.	
			Total.	Dissolved.	Organic. Total.	Organic. Dissolved.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Volatile.					
Crude Sewage — Concluded.																	
Nov. 9, 1906.....	12:01 A.- 8:00 A.....	59	28	17	8.1	3.4	13.3	0.00	0.0	14	59	32	18	0.0	.....	19	
Nov. 9, 1906.....	8:00 A.- 11:30 P.....	59	57	25	19.4	5.2	26.6	0.00	0.0	34	99	62	60	0.0	.....	29	
Weighted Av'ge.		59	47	22	16.0	4.6	22.2	0.00	0.0	27	86	53	46	0.0	.....	26	
Average	Nov. 8-9, 1906.	59	59	24	17.9	5.1	20.7	0.00	0.0	25	90	58	48	0.0	.....	26	
April 9, 1907.....	12:01 A.- 7:30 A.....	52	19	11	7.0	3.0	9.0	0.15	0.0	43	35	26	36	0.4	.....	72	
April 9, 1907.....	8:00 A.- 11:30 P.....	52	45	37	24.0	16.0	16.0	0.06	0.0	53	48	26	24	0.1	.....	64	
Weighted Av'ge.		52	36	28	18.0	11.7	13.7	0.09	0.0	50	44	26	28	0.2	.....	66	
April 10, 1907....	12:01 A.- 7:30 A.....	52	18	12	8.0	4.0	10.0	0.18	0.0	47	32	17	29	0.0	.....	41	
April 10, 1907....	8:00 A.- 11:30 P.....	52	34	23	17.6	9.8	21.0	0.01	0.0	49	46	26	24	0.4	.....	67	
Weighted Av'ge.		52	29	19	14.4	7.9	17.3	0.07	0.0	48	41	23	26	0.3		58	
Average	April 9-10, 1907.	52	32	24	16.2	9.8	15.5	0.08	0.0	49	43	25	27	0.2	.....	62	

Septic Sewage.

May 23, 1906....	6:00 A.-	6:00 P.....	51	50	40	37.0	....	20.0	0.00	0.0	...	131	92	....	0.0	.....	....
May 23-24, 1906..	6:00 P.-	6:00 A.....	51	41	33	16.3	....	20.0	0.00	0.0	...	79	30	....	0.0	.....	....
Weighted Av'ge.			51	46	37	26.7	....	20.0	0.00	0.0	...	105	61	....	0.0	.....	....
May 24, 1906.....	6:00 A.-	6:00 P.....	51	53	29	28.4	....	20.0	0.00	0.0	...	41	18	....	0.0	.....	....
May 25-26, 1906..	6:00 P.-	6:00 A.....	51	52	40	21.2	....	20.0	0.00	0.0	...	81	35	....	0.0	.....	....
Weighted Av'ge.			51	53	35	24.8	....	20.0	0.00	0.0	...	61	27	....	0.0	.....	....
Nov. 8, '06, Influent Filter No. 1.	5:00 A.-	7.40 A.....	58	90	....	22.6	8.4	25.0	....	....	...	159	75	....	0.0	.....	....
Nov. 8, '06, Influent Filter No. 3.	7.40 A.-	9:15 A.....	58	66	....	22.7	4.5	23.3	....	....	...	152	74	....	0.0	.....	....
Nov. 8, '06, Influent Filter No. 5.	9:15 A.-	10:00 A.....	59	60	....	22.7	4.5	23.3	....	....	...	145	75	....	0.0	.....	....
Nov. 8, '06, Influent Filter No. 1.	10:40 A.- 2:40 P.-	12:00 Noon. 4:00 P.....	57	72	....	21.8	6.0	21.0	....	....	...	202	107	....	0.0	.....	....
Nov. 8, '06, Influent Filter No. 3.	12:00 Noon- 4.00 P.-	1:20 P..... 5:20 P.....	58	63	....	21.8	4.4	21.0	....	....	...	228	135	....	0.0	.....	....
Nov. 8, '06, Influent Filter No. 5.	1:20 P.-	2.40 P.....	58	76	....	22.6	6.8	25.0	....	....	...	168	98	....	0.0	.....	....
Average			58	71	....	22.3	5.8	23.1	....	....	..	176	94	....	0.0	.....	....
Nov. 8-9, Influent Filter	4:40 P.-	6:00 A.....	58	62	25	20.6	3.2	27.0	....	....	...	120	89	....	0.0	.....	....
Nov. 9, 1906.....	8:45 A.-	4:45 P.....	58	..	....	....	....	....	....	....	...	100	66	....	0.0	.....	....
Weighted Av'ge.	Nov. 9, 6:00 A.-	4:45 P.										135	....	....	....	.....	....
April 9, '07, Influent Filter No. 2.	7:00 A.-	4:30 P.....	52	34	....	6.0	....	16.0	....	....	...	44	28	....	0.0	.....	....
April 9, '07, Influent Filter No. 4.	7:00 A.-	4:30 P.....	..	32	....	4.8	....	16.0	....	....	...	38	23	....	0.0	.....	....
April 9, '07, Influent Filter No. 6.	7:00 A.-	4:30 P.....	..	36	....	6.8	....	16.0	....	....	...	48	28	....	0.0	.....	....
Average	Influent, Apr. 9. 7:00 A.-	4.30 P.....	..	34	....	5.9	....	16.0	....	....	...	43	26	....	0.0	.....	....

TABLE NO. 72 — Continued.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.														Remarks.
			Oxygen Consum'd.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.	
			Total.	Dissolved.	Organic Total.	Organic Dissolved.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Volatile.					
Septic Sewage — Concluded.																	
April 9-10, 1907...	4:30 P.- 7:00 A.	51	28	....	20.8	....	20.0	....	....	...	42	25	....	0.0	.....	....	
April 10, 1907....	7:00 A.- 4:00 P.	52	34	....	12.4	....	20.0	0.06	....	...	47	24	....	0.0	.....	....	
April 10-11, 1907..	4:30 P.- 7:00 A.	51	58	....	11.2	....	21.0	....	....	...	38	17	....	0.0	.....	....	
Effluent Contact Filters.																	
May 23, '06, Filter No. 1.....	1st filling after 6:00 A.	..	..	....	17.5	....	14.0	....	....	...	29	21					
May 23, '06, Filter No. 5.....	9:15 A.- 10.05 A.	..	17	....	18.7	....	13.6	0.08	0.0	...	31	23					
May 23, '06, Filter No. 3.....	10:30 A.- 11:35 A.	..	15	....	18.7	....	15.2	0.04	0.0	...	15	13					
May 23, '06, Filter No. 1.....	1:00 P.- 1:45 P.	62	14	....	18.3	....	14.0	0.03	0.0	...	14	9					
May 23, '06, Filter No. 5.....	1:45 P.- 2:25 P.	60	19	....	18.7	....	16.0	0.03	0.0	...	8	6					
May 23, '06, Filter No. 3.....	2:25 P.- 3:00 P.	52	22	....	18.1	....	16.8	0.01	0.0	...	23	13					
May 23, '06, Filter No. 1.....	3.30 P.- 4:30 P.	51	20	....	21.5	....	15.2	0.03	0.0	...	11	8					
														Average 0.1			

May 23, '06, Filter No. 5	4:45 P.-	5:30 P.	51	18		21.1		15.2	0.08	0.0		26	18					
May 23, '06, Filter No. 1	6.30 P.-	7:30 P.	51	18		19.1		15.2	0.15	0.0		21	11					
May 23, '06, Filter No. 5	7.45 P.-	8:20 P.	51	19		19.9		16.0	0.20	0.8		24	19					
May 23, '06, Filter No. 2	11:00 P.-	11:50 P.	48	16		16.3		12.0	0.50	0.0		18	....					Filter resting three days.
May 24, '06, Filter No. 3	1:00 A.		44	16		24.7		10.0	0.20	0.2		18	8					
No. 1	2:30 A.		42	19		24.3		14.8	0.05	0.0		46	12			Av. 0.1		
No. 5	5:30 A.		48	18		21.1		10.0	0.34	1.2		39	10					
Average	Night effluent		55	17		19.8		14.1	0.12	0.2		23	12					
May 24, 1906	6:00 A.-	6:00 P.	63	18		16.7		11.2	0.60	0.0		24	9					
May 24-25, 1906	6:30 P.-	6:30 A.	63	18		16.6		11.6	0.00	0.0		17	9					
Nov. 8, '06, Filter No. 1	9:15 A.-	10.40 A.	54	17		8.8		15.0	0.20	7.6		47	32			0		
Nov. 8, '06, Filter No. 3	10:40 A.-	11:20 A.	54	22		8.6		12.0	0.15	8.0		60	42			0		
Nov. 8, '06, Filter No. 5	12:00 Noon-	12:45 P.	53	15		8.8		11.0	0.10	11.0		52	34			0		
Nov. 8, '06, Filter No. 3	2:40 P.-	3:00 P.	53	33		8.2		12.4	0.12	3.0		58	30			0		
Nov. 8, '06, Filter No. 1	1:20 P.-	2:00 P.	53	23		9.8		17.2	0.08	0.6		55	27			+		
Nov. 8, '06, Filter No. 5	12:00 Noon- 4:00 P.-	12:40 P. 4:45 P.	54	23		7.8		12.0	0.02	6.0		48	27			+		
Average	Day effluent		54	22		8.7		13.3	0.11	6.0		53	32			+		
Nov. 8-9, 1906	4:40 P.-	6:00 A.	55	22	15	7.8		24.0	0.03	0.0		38	25			+		Contn'us operat'n
Nov. 9, 1906	9:00 A.-	4:05 P.	56	20	13	9.4		14.4	0.09	0.6		51	35			+		Decided odor.

TABLE NO. 72 — Concluded.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts Per Million.														Remarks.
			Oxygen Consum'd.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.	
			Total.	Dissolved.	Organic. Total.	Organic. Dissolved.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Volatile.					
Effluent Contact Filters — Concluded.																	
April 9, '07, Filter No. 2.....	7:00 A.- 4:30 P.....	48	19	....	4.0	....	11.0	0.06	0.0	...	13	6	....	0.7	Chm. odor ++	....	
April 9, '07, Filter No. 4.....	7:00 A.- 4:30 P.....	48	15	....	2.0	....	8.0	0.07	2.0	...	8	4	....	0.7	+sl.+	....	
April 9, '07, Filter No. 6.....	7:00 A.- 7:30 P.....	48	13	....	3.0	....	7.0	0.10	....	...	16	12	....	0.7	+sl.+	....	
Average	Day effluent	48	16	....	3.0	....	8.6	0.08	0.7	...	12	7	....	0.7	+	....	
April 9-10, 1907..	4.30 P.- 7:00 A.....	49	9	....	6.0	....	16.0	0.12	1.0	...	8	....	....	2.0	Chm. odor ++	....	Night operation
April 10, 1907....	7:00 A.- 4:00 P.....	50	15	....	6.8	....	8.0	0.10	0.0	...	19	....	....	0.4	++	....	Night operation.
April 10-11, 1907..	4:30 P.- 7:00 A.....	50	16	....	12.0	....	20.0	0.01	0.0	...	36	....	....	0.8	++	....	
Effluent Sand Filters.																	
May 23, 1906.....	6:30 A.- 6:30 P.....	53	14	....	13.6	....	11.0	0.20	2.0	...	24	11	....	....	0	....	
May 23-24, 1906..	6:00 P.- 6:00 A.....	50	14	....	15.1	....	10.0	0.20	0.2	...	5	....	....	....	+	....	
May 24, 1906.....	6:30 A.- 6:30 P.....	60	14	....	11.5	....	9.5	0.12	1.2	...	15	4	....	....	0	....	

May 24-25, 1906..	6:30 P.-	6:30 A....	50	13	....	15.9	....	12.5	0.09	1.0	...	6	...	...	...	0	....
Nov. 7, 1906.....	10:30 A.-	5:30 P....	50	18	....	7.4	....	7.0	0.12	12.0	...	40	25	...	...	0	....
Nov. 7-8, 1906....	6:00 P.-	6:00 A....	46	15	12	8.4	....	13.8	0.02	0.0	...	29	22	...	...	+	....
Nov. 8, 1906.....	10:00 A.-	4:30 P....	53	14	9.1	9.8	....	10.4	0.14	6.8	...	26	20	...	...	0	....
April 9, 1907.....	10:00 A.-	4:30 P....	45	9	....	3.0	....	5.0	0.10	15.0	...	5	...	...	4.3	00	....
April 9-10, 1907....	4:30 P.-	7:00 A....	46	10	....	10.6	....	11.0	0.11	4.0	...	12	...	...	2.8	++	.... Night operation.
April 10, 1907....	9:00 A.-	4:00 P....	46	6	....	10.0	....	10.0	0.09	8.0	...	7	...	...	4.7	00	....
April 10-11, 1907..	4:30 P.-	7:00 A....	47	10	....	5.6	....	16.0	0.03	2.4	...	12	...	...	2.4	++	.... Night operation.

PLAIN CITY.

The village of Plain City is in Madison County on the banks of Big Darby Creek at a point where the stream has a watershed of about 268 square miles and a dry weather flow of perhaps 2 to 3 cubic feet per second. The village at the present time (1907), according to local authorities, has a population of about 1,800. The public water supply for the village was installed in the year 1894 and is derived from driven wells. The daily water consumption in 1906 was on the average 375,000 gallons. Public improvements include street paving, a system of storm sewers and a system of sanitary sewers which were constructed in 1902. There are at the present time about 3½ miles of brick pavement.

SEWERAGE.

The sanitary sewer system of Plain City comprises about three miles of pipe sewers which range in size from 8 to 15 inches. The system contains 12 flush tanks and 46 manholes. None of the industries of the village contribute manufacturing waste, and the sewage is practically entirely domestic, except that from a small creamery which is connected to the sanitary sewers. Out of the total population there are only about 150 connections; the persons served are estimated at 725. Eleven business blocks, 3 factories, 2 hotels, 2 banks, and 4 public buildings are included in the above connections. While the sanitary sewer system of Plain City was planned to be strictly on the separate plan, very little attention has been paid to the matter of taps and no definite regulations are in vogue regarding the tapping of the sanitary sewers. In view of this condition, a large number of down spouts have been connected to the sewers. a feature which causes a tremendous volume of sewage at times of rain.

Another interesting and unusual feature in connection with the use of the sanitary sewers of Plain City is the fact that practically each house using the public water supply is provided with an outside hydrant. These outside hydrants are practically universally drained into the sanitary sewers. The water mains of the village are in many places said to be laid within 18 inches of the ground, and during the hot months the water consequently attains a considerable temperature. With a view to obtaining as cold a water as possible and further because of the supposition that a more wholesome water may be obtained, it is the general practice to allow the outside hydrants to run continuously year in and year out. It is obvious that this practice has a marked effect upon the volume and character of the crude sewage, and that it also represents a needless waste of the public water supply.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

When the sewering of Plain City was proposed in 1902, it became necessary to provide for the purification of the resulting sewage in view of the small flow of Big Darby Creek and the probability of a marked nuisance, should the discharge of sewage be allowed to take place in the raw state. Big Darby flows south-easterly and joins the Scioto River near Circleville, which obtains its water supply from an infiltration gallery located along the shore of Big Darby; but there is practically no community which obtains water directly from the Big Darby Creek or the stream into which it finally flows. However, to remove all possibility of a local nuisance at the point of discharge of the sewage of the town into the creek, plans for the purification of the sewage were developed and were

submitted to the State Board of Health which in October, 1902, approved plans for the sewering of the village and the purification of the sewage. The plant as approved comprises the sedimentation of the sewage in septic tanks, followed after aeration by treatment in contact filters which were to be flooded and discharged automatically by an apparatus of special design.

EXAMINATIONS AND INSPECTIONS.

This plant was examined in detail on July 31-August 2, 1906. Visits for inspection were made on April 7, 1906, and in 1907 on March 11 and November 7.

DESCRIPTION OF PLANT.

The Plain City sewage purification plant, as constructed in 1902, is located on a 7.5-acre tract of land owned by the village and situated on the bank of the Big Darby Creek and adjacent to the Pennsylvania Railroad. The nearest house is about one-quarter mile distant.

Grit Chamber.

The crude sewage flows to the plant through the 15-inch main sewer into a grit chamber 2′ x 3′ in plan, 3′-9″ deep, and closed with a wooden cover. This chamber is constructed of concrete; the walls are 9 inches thick and the base 6 inches. The invert of the main sewer at both the inlet and the outlet is 18 inches above the bottom.

Septic Tanks.

The sewage next flows into the septic tanks which are two in number and are constructed of concrete. Each tank is 8 feet by 13 feet 1 inch in plan and 9 feet deep. The depth to the flow line is 8 feet. The capacity of each tank is about 6,250 gallons, and the total capacity of the two tanks is 12,500 gallons. The walls and bottom are constructed of concrete, the former are 24 inches thick and the latter 6 inches thick.

Inlets and Outlets. Sewage from the small grit chamber flows into an inlet channel which is 12 inches square in cross section and extends the entire length of the two tanks. There are two inlets in each septic tank. They are constructed of 4-inch vitrified sewer pipe and enter the tanks through 45 degree elbows. One end of the pipe is flush with the bottom of the inlet channel, and the other end is 2 feet 6 inches below the flow line of the tank. The inlets are 2 feet from the sides of the tank and are 4 feet apart. The outlets from the septic tanks, four in number, — two from each tank — are similar to the inlets and are located in an outlet channel similar in size and construction to the inlet channel. The tanks are not covered. A gas pipe railing about 4 feet high is constructed completely around the tanks.

Baffles. No baffles are provided.

Sludge Drain. The tanks are water-tight, concrete compartments and contain no sluice gates nor other drains for removing sludge or sewage.

Method of Control. The flow of sewage alone determines the period of retention in the tanks, although the inlets may readily be plugged in order to shut off the flow from a given tank.

By-pass. It is not possible to by-pass the crude sewage, although were the inlets plugged, sewage could be discharged from the inlet channel to low land and would eventually reach the creek.

Aerating Channel. The sewage from the outlet channel flows through an 8-

inch iron pipe, 2 feet 2 inches long, into an aerating chamber which contains 3 iron disks set 6 inches apart vertically. The top disk is 12 inches in diameter, the second 20 inches, and the third 2 feet 6 inches. The disks are of iron with serrated edges and are supported on a 2-inch standard square iron bar with a 1-inch square iron bar footing 14 feet long embedded in a concrete base. The aerating chamber is 3 feet long, 6 feet wide and 2.5 feet deep. Its bottom is divided by a concrete central baffle into two depressions 8 inches wide and 8 inches deep, which extend the full length of the chamber. From these depressions the sewage flows, respectively, to two distributing manholes. The bottom of the chamber is constructed of 12-inch concrete.

Sludge Disposal Area.

No area was provided originally for disposing of sludge from the septic tanks. As discussed beyond, (see page 567), in 1906 sludge was discharged into a trench on low land near Big Darby Creek.

Filters.

The last step in the purification of the Plain City sewage consists in oxidation in contact filters. These are six in number, each with an effective area of 506 square feet or 0.0116 acre, or a total of 0.07 acre. The superficial area is 729 square feet, and hence the total superficial area of the plant is 4,374 square feet or about 0.1 acre. The bottom area is 18 feet x 18 feet, or 324 square feet. The basins are merely excavations in the original soil and are not concreted. The filters are surrounded and separated by earth embankments. In the spring of 1907 a levee about 4 feet high was constructed with a view to protecting the plant from floods.

Filtering Material. The most readily obtainable filtering material was cinders which were procured from Columbus. These are 3 feet deep and range in size roughly from 1/16-inch to ¾-inch. Considerable coarse material is also present.

Underdrains. The filters are underdrained by a 6-inch drain of bell and spigot vitrified sewer tile which extends through the center of each unit. Two lateral lines of 4-inch pipe are laid at right angles to the main drain and are 5 feet apart. No lantern holes nor other means of ventilation and no coarse material are provided.

Dosing Devices. The operation of the plant was intended to be automatically controlled at all times. A dosing manhole is provided for each set of three filters, in which there is placed a special apparatus consisting of a three-way pipe of galvanized iron supported on a ball and socket joint. This pipe practically serves as the extension of the pipe which leads from one of the depressions at the bottom of the aerating channel. The manhole is itself divided into three triangular compartments by means of concrete walls in which are galvanized iron floats. These compartments are cross connected, respectively, to the three units to be filled from a given dosing manhole. The result expected from this apparatus was that as a filter was filled with sewage the water would rise in the compartment in the dosing manhole to which it was connected by a 1½-inch pipe, and when full would force upward the galvanized iron float sufficiently to tip the three-way iron trough, and would thus divert the flow of sewage on to the next filter in rotation. The manhole which contains the dosing apparatus is provided with a 2-inch hinged wooden cover.

Distribution Devices. The main sewage carrier from the depressions in the bottom of the aerating chamber consists of an 8-inch vitrified pipe which is branched to each set of three filters. Each of these pipes terminates in a distribution manhole just described. These manholes are constructed of one course of brick and are 4 feet 4 inches in diameter and 4 feet deep. The distribution of sewage

on to the filters themselves is effected by about 12 feet of 6-inch half tile laid on the surface of the filters at right angles to the sides.

Effluent Discharge. The automatic discharge of the filters when operated on the fill-and-draw plan was intended to be effected by means of 3-inch siphons provided with ⅜-inch air valves controlled by a lever arm and weight. The confined air was intended to be released by the rise of a float. The siphon chambers, similar to the triangular compartments in the dosing manholes, are cross connected to the several filters so that the discharge from the filter filling would cause a rise of the float in the siphon chamber, and would thus permit the discharge of the unit which had been held in contact while the filter next in rotation was being filled. One discharging siphon is provided for each filter.

The discharge from the several siphon chambers takes place through about 200 feet of 10-inch vitrified sewer pipe which terminates on the bank of Big Darby Creek. For some time past the entire operation of the plant has been on the continuous basis and the discharge has taken place by gravity.

On acount of its location, the plant is subject to inundation by floods. With a view to preventing the inroads of currents during high water, in the spring of 1907, a 4-foot embankment was constructed on the creek side of the plant. A 12-inch vitrified pipe culvert is provided in the embankment, since during floods the water backs up in the effluent pipe, which is without a back flooding gate, and at the same time sewage discharges from the village and tends to fill the space on the inside of the embankment. By virtue of the pipe culvert, however, it is now possible to maintain the same level outside and inside the embankment and thus prevent serious washing of the protecting levee.

SEWAGE FLOW.

Observations of the flow of sewage were made on the one detailed examination and were carried out for 24 hours. These measurements were made during dry weather and the average flow was found to be at the rate of 175,000 gallons in 24 hours. The maximum and minimum rates of flow were, respectively, 250,000 and 138,000 gallons and occurred at 8:00 o'clock A. M. and 2:30 o'clock A. M., respectively. At this time, it is estimated that 500 persons were tributary to the sewers, so that the above average flow expressed in gallons per person tributary was the very high figure of 350 gallons. This very high flow during dry weather is to be chiefly attributed to the use of outside hydrants, as already mentioned. It is probable that the night flow is almost entirely to be ascribed to this practice.

The visit of March 11, 1907, was made after a somewhat extended period of wet weather, and the estimated sewage flow at that time was at the rate of 720,000 gallons in 24 hours. It was learned, during this investigation, that there is considerable ground water leakage into the sewers and that roof and storm water greatly increase the flow during storms.

COMPOSITION OF CRUDE SEWAGE.

The analytical data presented beyond and obtained on the detailed examination of this plant, include weighted average analyses of the crude sewage for 24 hours. As these analyses indicate and as naturally follows from the very high sewage flow, the sewage of the village is exceptionally weak. It is generally well aerated and contains both nitrites and nitrates. The suspended matters are granular and the sewage contains practically no colloidal matter. The sewage on all visits has appeared to be essentially domestic and creamery wastes have been little in evidence.

OPERATION.

The operation of this plant is under the general charge of the sewer committee of the village. During this investigation, it has been under the direct charge of the superintendent of streets who also assumes the duties of health officer. Occasionally, extra labor is engaged to assist in the operation of the plant. In general, prior to this investigation but little attention was paid to the plant, but as a result of the investigation considerable interest was awakened and there has been a decided increase in the care and attention given the plant.

Septic Tanks.

Since constructed, both septic tanks have been in use at the same time. Even under normal conditions the period of flow has been very small, and according to weather conditions has ranged from perhaps 30 minutes to 2 hours. On the first visit, the tanks were found to be almost filled with sludge which was 7 feet deep at the inlets and 8 feet deep at the outlets. The tanks had never been cleaned. In view of this large sludge accumulation, the actual period of flow up to the first visit during this investigation has perhaps been only a few minutes.

Acting under advice from the State Board of Health, the sludge was removed from the tanks in the spring of 1906. Following this cleaning, there was a gradual accumulation of sludge which was variable in quantity, especially as the high sewage flows would tend to produce a scouring action in the tanks. It was learned that it had been the practice to stir the contents of the tanks with a pole with a view to causing the sludge to pass out of the tank with the effluent.

On the detailed examination, it was noted that the first septic tank receives the larger part of the sewage due very probably to stoppages of the inlet elbows by rags and paper, which, owing to the velocity of the incoming sewage, do not deposit until they have passed the two openings which lead into the first septic tank. According to the superintendent, these inlet openings clog frequently and it is necessary to remove the obstructions from two or three times a day, in order to insure that the second tank is receiving its proportionate share of sewage. During winter weather, especially when the volume of sewage is high, this feature of clogging of the inlets causes the sewage to overflow the tanks as was the case in the winter of 1907, when the adjacent filter embankments were washed away and sludge was deposited over a considerable area. No scum has formed on the tanks.

The outlets, similarly, have been at times clogged with sludge. Clogging became so serious in the spring of 1906 that the areating device was choked so that the sewage was flowing for the greater part only to the north side of the plant.

Filters.

Prior to this investigation, the filters received practically no attention; the surface of the coke was clogged with sludge and by a rank growth of vegetation.

Moreover, owing to lack of attention, the automatic devices had begun to deteriorate. On the first visit, it was brought out that the filters were badly clogged, that the surface material was not level, that the distribution was poor and that the application of sewage was confined to a very restricted area. It was stated that the automatic apparatus had never been in successful operation, and that since first placed in service, the filters had been operated continuously with open outlets. At that time, the filters were operated in sets of three; the two sets were being used alternately for weekly periods. As a result of the first visit, the State Board of Health advised that the filters be cleaned and leveled and that they be used strictly in rotation. On the next visit it was found that the filters had received considerable attention as they had been cleaned and leveled, but the dis-

tribution was again found to be poor and vegetation was noted on the surface of the filters. After the cleaning of the septic tanks, it was attempted to operate the filters on the fill-and-draw basis, but this attempt did not prove to be successful. The general appearance of the plant indicated that it received too little supervision for best results.

In accordance with the above recommendations, in the summer of 1906, the filters were again cleaned and leveled and short lengths of half tile were provided to improve the distribution. A slimy mat was noted on the filtering material and marked evidence of clogging were noted, however, even after these changes were made. On the final visit in the fall of 1907, all of the six filters were in use. The plant appeared to be much more efficiently operated than was the case on former visits and it was evident that more attention had been given to its care.

Based on the average sewage flow of about 175,000 gallons in 24 hours, the average rate of operation is about 2,500,000 gallons per acre in 24 hours. Owing to the largely increased flow during storms the actual rate of filtration no doubt has been decidedly higher than the above figure. Based on the 725 persons, estimated in 1907 to be tributary to the sewers, the plant has been operated on the basis of 10,400 persons per acre, or 3,470 persons per acre-foot

Sludge Disposal.

As advised by the State Board of Health, the septic tanks were cleaned in the spring of 1906. To receive the sludge. in the low land adjacent to the plant there was excavated a trench 12 inches wide and 6 inches deep, several hundred feet in length. About one-fourth of the sludge, which amounted to approximately 40 cubic yards, was pumped from the tanks by an ordinary hand operated pitcher pump with a 4-inch suction. The remainder was so thick that the pump could not be operated and it was then necessary to remove the sludge by hand. It was stated that a scaffold was built in the tank from which buckets could be lowered and filled with sludge. The full buckets were then passed to men above, who deposited the sludge into trenches whence it flowed to low land near the creek. No odor is said to have been noticeable, not even on the part of the men working in the tank. The sludge when removed possessed a deep black color, but on exposure to the air soon turned brown, and when examined on August 2, 1906, perhaps 4 months later, had almost entirely oxidized, was without odor and was practically humus matter. It is of interest to note that soon after the removal of the sludge, there grew up in the drying deposit a very large number of tomato plants.

EFFICIENCY.

Although prior to this investigation the plant had received practically no supervision and although the filters were badly clogged owing to poor distribution, even under the operation of the contact filters on a continuous basis, the effluent has been non-putrescible. No odors are noticeable about the plant and in general the sewage of the village is disposed of without nuisance. These somewhat remarkable results are very probably due to the weakness of sewage which, when freed from suspended matter, is ordinarily but slightly putrescent. It is, moreover, probable that were the sewage stronger it would not be possible successfully to operate the filters on a continuous flow basis.

Septic Tanks.

The septic tanks, as is indicated by previous discussion, have proved to be very inefficient in the removal of suspended matter as a general average. In fact, the periodic discharge of heavy matters, owing to the violent evolution

of gas from the sludge, has been in a large part responsible for the clogged condition of the plant and the poor efficiency which has at times prevailed. Occasionally, however, the septic tanks have served to remove considerable suspended matter from the crude sewage. On the detailed examination made during this investigation, of the 23 parts per million of suspended matter in the crude sewage, only 18 parts were found in the average septic effluent, a removal by the tank of 22 per cent. The rapidly accumulating sludge and the feature of a very high sewage flow during storms, and the scouring action then prevailing in the tanks, however, suggest that as a general average the efficiency of these tanks is very low and that they are of but small benefit as a preparatory treatment of the village sewage.

On all visits active fermentation has been noted in the sludge in the septic tanks. As before stated, the weak crude sewage contains considerable dissolved oxygen and on the single examination of this plant the effluent from the septic tanks also contained dissolved oxygen as is indicated by the following results.

TABLE NO. 73.

Dissolved Oxygen in the Applied Sewage and in the Effluent of the Septic Tanks on August 1-2, 1906.

Hour.	Temp. Deg F.		Dissolved Oxygen. Parts Per Million.	
	Sew.	Eff.	Sew.	Eff.
8:00 A. M.	57	57	3.6	5.2
12:00 Noon	57	59	4.2	4.4
4:00 P. M.	59	58	4.3	4.4
8:00 P. M.	58	59	4.4	5.2
12:00 P. M.	59	59	6.5	5.4
4:00 A. M.	59	59	7.0	6.1
Average	58	59	5.2	5.1

FILTERS.

Analytical data obtained during this investigation and results of inspections strongly indicate that the septic effluent after passing continuously through these shallow coke filters is purified to a point of ultimate stability. The crude sewage, the septic sewage and the final effluent have alike been well oxygenated and all have contained nitrogen as nitrates. In view of the fairly heavy load on these filters on the basis of population tributary per acre, it seems to be true that their success in the final purification of the sewage of this plant, is largely to be attributed to the exceedingly dilute crude sewage and to the fact that the putrescible matters carried by the raw sewage are for the greater part not in solution, but in suspension.

SUMMARY.

The results of this investigation show that prior to 1906 the plant received practically no supervision and that it was allowed to deteriorate. The septic

tanks, distributing devices and filters rapidly clogged with sludge and the automatic apparatus which received practically no attention became rusted and could not be used, although it appears that since it was installed it has never been in successful operation. Practically since construction, these cinder filters have been operated continuously and the distribution, although improved during this investigation, has in general been very inefficient. Notwithstanding lack of supervision and care, the plant has probably at all times produced a non-putrescible effluent and the purification of the sewage of the village has been carried out with no attendant odors and with no nuisance and to a degree sufficient to correspond to local requirements.

It is strongly indicated from results available during this investigation that the successful operation of the plant by the application of sewage continuously to coarse material of this kind, is very largely due to the weakness of the crude sewage, and that otherwise very little purification would be brought about. Notwithstanding, it is recommended that steps be taken to metering the water supply, in order to reduce the present enormous waste of water. It is further suggested that strict regulations be adopted and enforced to prevent the entrance of roof water into the sanitary sewers. It should be noted that the supervision of the plant has decidedly improved and that at the close of 1907, the plant was being faithfully operated to the best advantage in view of the enormous flow of sewage, the effect of storms, and the impracticability of operation on a fill-and-draw basis. The plant is unfortunately located with respect to the creek, as in certain seasons it is entirely inundated. The protecting levee built in 1907 was a great improvement, but, of course, floods in the Big Darby cause the direct flow of raw sewage into the creek, a feature which, except on hygienic grounds, of course, can not be criticised owing to the high dilution then available.

COSTS.

The bond issue for the sanitary sewers and for the sewage purification plant was $19,000. No detailed information is available as to the detailed cost of the plant.

The operating expenses have been small and prior to 1906 there were practically none. During this investigation, however, the plant has received fairly regular supervision by the superintendent of streets. This official received a salary of $40 per month in 1906 and $50 per month in 1907. In 1906 he paid $20 for rent of corporation land, but this charge was remitted in 1907. Perhaps $125 per year would be a fair estimate of the street commissioner's time.

Operating costs for the years 1906 and 1907 were about $181 and $199, or in terms of the tributary population 25 cents and 27 cents, respectively.

In 1906, seven weeks are said to have been required in cleaning the plant. This work was done by the street commissioner unassisted.

The disposal of sludge from the septic tanks cost $50 or roughly at the rate of $1.25 per cubic yard. The village records show the following labor items for cleaning the septic tanks:

Two men, 10 days, at $1.50=	$30
Street Commissioner, 10 days at $2.00=	20
Total	$50

In 1907, the construction of the protecting levee cost $59.25 as follows:

Three men 1½ days, at $1.50=	$6.75
700 cu. yds. earth, at 7½ cts. per cu. yd.=	52.50
Total	$59.25

TABLE NO. 74.

Results of Chemical Analyses.

Date 1906.	Hour of Collection.	Temp. Deg. F.	Parts per Million.														Remarks.
			Oxygen. Consumed.		Nitrogen As					Chlorine.	Suspended Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats	
					Organic		Free Ammonia.	Nitrites.	Nitrates.								
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.					
Crude Sewage.																	
Aug. 1, 1906.....	6:00 A.-10:00 P.	58	15	14	1.4	0.6	0.8	0.13	2.4	44	26	20	0.0	4.2	....	12	Air temp. 78
Aug. 1-2, 1906....	10:00 P.- 5:30 A.	59	8.4	7.2	1.0	0.6	0.3	0.08	3.0	46	16	11	0.0	6.8	....	3	
Weighted Av'ge.		58	12.8	11.7	1.3	0.6	0.6	0.11	2.6	45	23	17	0.0	5.1	....	9	
Septic Sewage.																	
Aug. 1, 1906.....	6:00 A.- 9:30 P.	59	12.1	.....	1.4	.....	1.0	0.30	2.0	42	21	16	....	4.8	....	....	
Aug. 1-2, 1906....	10:00 P.- 5:30 A.	59	7.8	.....	1.2	.....	0.4	0.15	2.6	46	11	7	0.0	5.0	....	....	
Effluent Filters.																	
Aug. 1-2, 1906....	6:00 A.- 5:30 A.	60	7.2	.....	0.3	.....	0.1	0.15	3.6	32	4	3	0.0	4.1	0	....	

WESTERVILLE.

Westerville is a village in Franklin County on Alum Creek about twelve miles north of the city of Columbus. The village is essentially a college town and is the seat of Otterbein University. According to local records, the population is about 1,500. There are practically no manufacturing interests in Westerville, with the exception of one small creamery. Prior to 1901, there were few public improvements, but in that year a public water supply was installed and in the following year there was constructed a system of sanitary sewers. At that time, none of the streets were improved, but in 1907 several streets were paved with brick. According to the village records, the daily water consumption is about 125,000 gallons.

The sanitary sewers comprise 4.7 miles of pipe sewers which receive the sanitary sewage of the entire village, with the exception of a few houses on low land west of Grove Street. Up to the present time (1907) practically no additions have been made to the sanitary sewers since construction. The sanitary sewers are chiefly constructed of 8-inch pipe, but near the purification plant the size is increased to 10 inches and finally to 12 inches. The sanitary sewage of the village is conducted by gravity to the plant. In addition to the sanitary sewers, there are a few sewers for storm water only. Based upon the dry weather sewage flow and the water consumption, it is estimated that there are about 300 persons tributary to the sanitary sewers.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

The natural drainage of the village is into Alum Creek at a point where the stream has a watershed of about 150 square miles, and as this stream is used as a partial source of the water supply of Columbus, in planning the sanitary sewers it was obligatory to provide for purifying the sewage. The plans for the sanitary sewerage system and for the purification of the sewage of the village were submitted to the State Board of Health and were approved by the Board in January, 1902. A modified site was also approved in June of the same year. The plans provided for the treatment of the sewage in septic tanks, followed by primary contact filters and secondary continuous filters. The plant was designed to treat 75,000 gallons of sewage in 24 hours. The septic tanks were designed on the basis of a 12-hour period of flow. The contact filters were to be flooded and discharged automatically and were to be operated at a rate of about 400,000 gallons per acre in 24 hours.

EXAMINATIONS AND INSPECTIONS.

Visits were made to this plant on Mar. 27, 1906, May 18-19, 1906 and April 29, 1907. That of May 18-19, 1906 was a detailed examination which covered 24 hours. In connection with cooperative work on disinfection, several visits were made in addition to those above recorded.

DESCRIPTION OF PLANT.

The site of the plant is a 3-acre plot of land just outside of the corporation line and on the bank of a small stream which flows into Alum Creek. The nearest house is 300 to 400 feet distant. The plant is hidden from view by a steep bank.

Grit Chamber.

The crude sewage without screening flows from the 12-inch main sewer into a small grit chamber 18 inches x 2 feet 6 inches in plan and 3 feet deep, with a capacity of about 80 gallons.

Septic Tanks.

From the grit chamber, the sewage flows directly into the septic tanks, two in number and constructed of concrete. The walls of the tank are 12 inches thick and the bottom is 6 inches thick. The tanks are each, 8 x 26 feet 1 inch in plan, 8 feet total depth, or 7 feet to the flow line and each has a capacity of about 11,000 gallons. The tanks are covered with a flat wooden roof which consists of 2-inch boards cleated together in about 8-foot lengths. There is, therefore, no head room and the absence of openings in the roof renders inspection somewhat difficult.

Inlets and Outlets. The inlet channel is 12 inches square in cross section and extends the entire length of the two tanks. Each tank has two 4-inch vitrified sewer pipe inlets which are set flush with the bottom of the inlet channel and enter the tanks through 45 degree elbows turned downward and terminating 2 feet 6 inches below the flow line of the tank. The inlets are spaced 4 feet apart. The outlets are similar in construction and arrangement.

Baffles. No baffles are provided.

Sludge Drains and Controllers. No sludge drains are provided and the floor of the tanks is level. The flow through the tank depends upon the discharge of crude sewage, but a tank may be put out of service by plugging the inlets.

By-pass. At the end of the inlet channel there is a 6-inch pipe which leads directly to the creek whereby sewage may be by-passed. The outlet is closed during dry weather by a cloth-wrapped wooden plug.

Aerating Chamber. From the outlet channel the septic sewage flows through an 8-inch iron pipe on to a series of three iron disks set 6 inches apart. These disks are provided with serrated edges and are supported on a 2-inch square iron bar with a 1-inch bar footing embedded in a concrete base. The disks are from top to bottom, respectively, 12 inches, 20 inches and 2 feet 6 inches in diameter. The aerating chamber itself is constructed of 12-inch concrete and is 3 feet long and 6 feet wide and 2 feet 6 inches deep. From a depression in the bottom 8 inches wide and 8 inches deep leads an 8-inch outlet pipe which supplies the contact filters.

Measuring Weirs. No means are provided for measuring the sewage flow.

Sludge Disposal Area.

The original design included no area for disposing of sludge, and when this became necessary in 1906, there were constructed on low land adjacent to the filters a series of shallow trenches.

Primary Contact Filters.

The septic effluent is first treated on six cinder filters originally planned for operation on the fill-and-draw basis. These filters each have an effective area of 0.021 acre and hence the total available effective area is 0.126 acre. The sides of the excavation slope 1-½ to 1, and, therefore, the total surface area is 0.16 acre and that of each unit 34.5 feet square of 1,180 square feet. The six units are separated by seeded earth embankments which surround the entire plant.

Filtering Material. The primary filters contain screened cinders which range in size from ⅛ to 1 inch. The specifications prohibit material which has more

than 20 per cent of particles 1 inch in size or more than 5 per cent of dust. The depth of the filtering material is 3 feet.

Underdrains. The filters are underdrained with a main drain of 6-inch vitrified sewer pipe laid with open joints and into which are branched two lines of 4-inch lateral drains spaced about 10 feet apart and extending across each unit at right angles to the main drain. The character of the filtering material is the same throughout its depth and there are no lantern holes nor other special means for ventilating the underdrains.

Dosing Devices. The apparatus originally planned for automatically flooding and discharging the contact filters is substantially the same as that at Delaware, Plain City and recently at London; the apparatus has not been successful. (For description see p 564.)

Distribution Devices. The sewage from the septic tanks is carried in an 8-inch vitrified pipe which extends from the bottom of the aerating chamber. Two right angle branches from the main line controlled by wooden shear gates allow the diversion of the sewage to the two sets of three contact filters. Each of these branches terminates in a distribution manhole 4 feet in diameter and 5 feet deep, which contains the dosing device. The distribution of sewage on the filters is effected by three short lengths of 6-inch vitrified pipe.

Effluent Discharge. The contact filters were intended to be automatically discharged by siphons. (For description see p 565). During this investigation, the outlets have been open and the effluent has flowed continuously from the filters by gravity.

Subsidiary Cinder Filters.

The original plans included the further treatment of the partially purified sewage on cinder filters operated continuously. These filters are two in number and one is provided for each set of three primary filters. The filters are separated by earth embankments which are about 4 feet above the level of the filtering material. The filters are, of course, located at a level several feet lower than that of the primary filters. Each has an effective area of 484 square feet or 0.011 acre. The surface area of each is 31 feet square and the total surface area is 1922 square feet or 0.044 acre.

Filtering Material. The filters are filled with cinders which range in size from ½ to 1 inch and are 6 feet deep.

Underdrains. Each filter is underdrained with one central 8-inch drain of vitrified pipe. No means of ventilation are provided and no coarse material is placed directly over the underdrain tile.

Dosing and Distribution Devices. The subsidiary filters receive the direct flow from the primary filters through an 8-inch pipe which discharges at the edge of each filter on its center line. The sewage is distributed on the surface of each filter by one line of 6-inch half tile laid with uncemented joints.

Effluent Discharge. There are two 8-inch outlet pipes, one from each subsidiary filter. One outlet is 50 feet long and the other 30 feet; both lead to the adjacent creek. The plant is located on somewhat elevated ground and hence there is no danger of interrupted operation due to high water.

SEWAGE FLOW.

There is considerable leakage into the Westerville sewers, as in many places they are laid in wet ground and hence during storms and wet weather the sewage flow is greatly increased. From measurements carried out on the detailed examination, the dry weather rate of flow averages about 36,000 gallons

in 24 hours. The maximum rate at this test was 61,000 gallons and the minimum rate at night was 15,000 gallons, a flow which indicates considerable leakage and some waste water. The above dry weather flow corresponds to 120 gallons per person tributary. An estimated rate of flow of 200,000 gallons was observed under wet weather conditions, on the inspection on June 14, 1907.

COMPOSITION OF CRUDE SEWAGE.

The high sewage flow during wet weather and the high per capita flow during dry seasons, indicates that ordinarily the sewage of the village is dilute. Inspection showed that the suspended matters are granular, that the sewage is practically free from colloidal matter. Available analytical data indicate that the sewage is fresh since it generally contains dissolved oxygen. The sewage is essentially domestic except for two or three hours in the morning when a small volume of washings from a creamery is discharged into the sanitary sewers. This creamery waste ordinarily is of little significance as regards the average sewage.

OPERATION.

This plant is under the general supervision of the mayor and village council, and its operation is included in the duties of the street commissioner. The plant, however, receives very little supervision and generally is entirely neglected.

Complaints regarding the condition of the plant were made to the State Board of Health early in January, 1906, and on January 9, 1906, the assistant engineer made an investigation and reported that the plant had not been operated for several weeks and that the crude sewage was being by-passed into Alum Creek and was consequently a distinct menace to this occasional source of water supply for the city of Columbus. (See report of State Board of Health, 1906, p. 14).

Similar conditions were found on the first inspection made during this investigation, on which the representative of the State Board of Health was accompanied by the health officer of Columbus. It was learned that the plant had never been operated on a fill-and-draw basis, owing to the failure of the automatic apparatus designed to accomplish this feature. Due to this cause, it was necessary to operate the plant continuously and owing to a lack of supervision the filters ponded and were greatly clogged with sludge. The inlets of the septic tanks were likewise clogged, the tanks themselves were almost filled with sludge and some of the concrete walls were breaking down.

Since the by-passing of the crude Westerville sewage was a constant menace to the water supply of Columbus, it was imperative to take steps to prevent the practice and to improve the general condition of the plant. The matter was informally discussed with the city officials who appeared somewhat indifferent to the necessity for improving conditions, but who agreed to place the plant in shape for satisfactory operation and to stop the discharge of unpurified sewage.

On the detailed examination which followed about seven weeks later, somewhat better conditions prevailed. Under pressure of the board of health of the city of Columbus, and due to threatened injunction suits in May, 1906, the village authorities instructed the street commissioner to clean the filters and to make all necessary improvements. At that time the surfaces of the filters were thoroughly cleaned and are said to have been dug over to a depth of about 6 inches. The inspection then made indicated that one of the septic tanks contained about 80 per cent. of sludge and scum and the other about 60 per cent. The inlet and outlet pipes were clogged with sludge and the effluent contained large quantities

of black suspended matter forced up by violent gas ebullition. It was strongly evident that the sludge should be removed from the tanks. Suggestions to this effect were accordingly made and this advice was acted upon in the summer of 1906. Following this, however, the plant was again seldom visited by the street commissioner, and, as noted on several visits during the disinfection experiments, the plant received practically no attention, although sewage was passed continuously through the filters and was not by-passed. The plant was visited again during this investigation on June 14, 1907, and very little change was noted in its general condition. The inlet piping on the septic tanks was found clogged so that the first tank received much more sewage than the second. Both septic tanks were in service and it was estimated that one of them contained about 3 feet of scum and the other about half this quantity. The effluent from the tank was apparently normal and there appeared to be no immediate necessity of cleaning the tanks. No odors were noted around the septic tanks, although the loose board covering permits the partial exposure of the sewage to the atmosphere. Three of the primary filters were in service and were covered with sludge. The rank growth of weeds on the filters and about the plant suggested that the entire plant again needed cleaning. The secondary filters were clogged and out of service.

In view of this condition, it was suggested that the sludge be removed from the filters, that they be raked at intervals and be kept free from weeds. The officials were urged to pay more attention to the operation of the plant, but judging from information since obtained it appears that the general neglect of the plant has continued. Based on the average sewage flow of 36,000 gallons the period of flow in the septic tanks is 14.6 hours and the corresponding linear velocity is about 0.15 m. m. per second. Of course. sludge accumulation has at times respectively decreased and increased these figures.

The continuous operation of the primary filters corresponds to an average rate for the entire area of 286,000 gallons per acre per day, or twice this rate when only three filters are used at once as has generally prevailed during this investigation. The rate is, of course, distinctly greater in wet weather, but the actual quantity of organic matter applied is substantially the same. The continuous or secondary filters have been operated at an actual rate of 3,280,000 gallons and at an average rate of 1,640,000 gallons per acre per day. The effective area of the primary filters corresponds to 2,400 persons tributary per acre, or 800 persons per acre-foot; similarly, the area of the secondary filters corresponds to 13,600 persons per acre or 2,270 persons per acre-foot.

Sludge Disposal.

As suggested by the State Board of Health, the septic tanks were cleaned in the summer of 1906. To receive the sludge, a shallow excavation was made on land lying between the filters and the stream. This crude settling basin was of such capacity that all of the sludge could be deposited in it without danger of leakage into the creek. The excavation was about 100 feet from the septic tanks.

In cleaning the tanks. it was first attempted to remove the sludge with a 4-inch hand operated diaphram pump. It was found, however, that only the small highly fluid portion of the sludge could be removed in this manner and in the case of the greater part of the deposit it was necessary to remove the sludge with buckets. The sludge removed, was discharged on to a wooden sluice erected near the tanks. The sludge flowed down this sluice into the shallow basin prepared for its reception. It is stated that there were no especially disagreeable odors noted and that practically no inconvenience was

experienced by the men engaged in the work. The sludge deposit was inspected seven weeks later and there was found a brown fairly hard mass which was without odor and was substantially humus matter. During the warm weather of the summer, a luxuriant growth of vegetation developed upon the dry sludge.

Unfortunately, no notes were taken regarding the labor and cost of this work, and it has not been possible to obtain information in further detail than the above.

EFFICIENCY.

From the above account of the lack of supervision at this plant, it would be inferred that the effluent is of poor quality. Analyses made during this investigation, together with those incidental to the supplementary work on disinfection show, however, that the weak sewage of the village after final treatment on the secondary filters is purified to a non-putrescible state. These results are obtained even though the filters are operated continuously, with poor distribution and heavy clogging.

On the single detailed examination, the effluent from the primary filters contained practically no nitrates, but considerable dissolved oxygen and was on the border line between non-putrescible and putrescible. The effluent from the secondary filters, however, was slightly nitrified and was non-putrescible. The analysis of the primary effluent made for some weeks during the disinfection studies and discussed beyond shows a fair degree of purification from even the primary filters until after a considerable period of continuous operation, when the effluent decidedly deteriorates and is finally highly putrescible. Interesting bacterial data, as regards the primary effluent from this plant are contained in the supplementary report on the disinfection of sewage effluents.

Similar conditions as to the actual operation of the plant were noted on the inspection of June, 1907. The plant continued to be in very poor condition, but the sewage was being purified without nuisance and the effluent was of low turbidity and without odor.

SUMMARY.

The Westerville sewage purification plant is a striking example of the result of the entire indifference of the officials as to the operation and maintenance of a plant of this type. Throughout this investigation, the plant has received practically no supervision and in the early months of the work the sewage was by-passed for long periods and tended to endanger the water supply of the city of Columbus. Under threatened legal proceedings, some effort was made by the village officials to improve conditions, but as indicated by this investigation, these efforts were only spasmodic and at its close the plant was in very poor condition. The entire failure of the automatic apparatus for operating the filters on a fill-and-draw basis shows how intermittently related to the success of contact filter operation are the automatic devices designed to accomplish this end.

Under obligatory operation on a continuous basis even in the face of very inferior distribution, the weak sewage of Westerville has been purified to a non-putrescible state and the disposal of the sewage of the village has been effected without nuisance. The design of the inlets of the septic tanks, is such that there have been frequent stoppages which have resulted in an unequal flow through the tanks. The septic tanks have generally been but little efficient, as the effluent has frequently contained large quantities of black suspended matter which has seriously clogged the cinder filters and has greatly detracted from the appearance of the plant.

With a view to improving conditions at this plant, it is recommended that it be visited daily by a caretaker who is especially engaged for this purpose; that the distribution of the septic effluent on the primary filters be improved by the use of branched half tile; that vegetation be removed from the filters and from the embankments from time to time; that the filters be raked and cleaned frequently; that two sets of three filters be used on alternate days and that an effort be made to arrange for other means for the removal of roof water which is now permitted to flow into the sanitary sewers.

COSTS.

The contract cost of the plant including septic tanks, filters and automatic apparatus was $2,900.

The operating costs have been very small. No information is available as to operating expenses entailed by the labor involved in cleaning the plant in 1906.

TABLE NO. 75.

Results of Chemical Analyses.

Date 1906.	Hour of Collection.	Temp. Deg. F.	Parts per Million.													
			Oxygen. Consumed.		Nitrogen As					Chlorine.	Suspend'd Matter.		Free Carbonic Acid.	Alkalinity.	Dissolved Oxygen.	Putrescibility.
					Organic		Free Ammonia.	Nitrites.	Nitrates.							
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.				
Crude Sewage.																
May 18, 1906.....	6:30 A.- 6:15 P.	50	31	11.0	10.2	2.8	11.8	0.00	0.2	76	118	74	35	506	....	....
May 18-19, 1906..	6:15 P.- 6:15 A.	53	11	4.8	2.6	1.3	6.8	0.08	0.2	74	41	28	20	438	3.6	..
Weighted Av'ge.		52	21	7.9	6.4	2.1	9.3	0.04	0.2	75	80	51	28	472	....	....
Effluent Primary Filters.																
May 18, 1906.....	7:00 A.- 7:00 P.	.....	12	.....	4.5	.....	10.5	0.13	0.8	.....	32	20	....	.....	....	....
May 18-19, 1906..	6:30 P.- 6:30 A.	.....	7	.....	1.8	.....	10.5	0.03	0.4	.....	15	8	....	.....	4.6	....
Effluent Secondary Filters.																
May 18, 1906.....	7:30 A.- 6:30 P.	.....	8	.....	2.9	.....	9.2	0.20	1.7	.....	35	14	....	.....	....	0
May 18-19, 1906..	7:00 P.- 7:00 A.	.....	5	.....	1.1	.....	9.4	0.08	1.0	.....	7	5	....	.....	6.1	0

EAST CLEVELAND.

The village of East Cleveland lies east of the city of Cleveland covering an area of about 10 square miles, some two miles south of the shore of Lake Erie. The village is chiefly residential and its rapid growth in recent years has led to many public improvements. According to local records the population in 1907 was about 8,000. Public improvements include electric lights, a complete system of sanitary sewers, a system of storm sewers, a sewage purification plant and a public water supply. Since the late nineties, arrangements have been made to obtain water from the city of Cleveland. The records of the water department indicate that the daily water consumption in 1906 was about 444,000 gallons and in 1907 about 448,000 gallons, of which 149,600 gallons are stated to have been used for manufacturing alone. The water consumption in 1907 was at the rate of 56 gallons per capita. Practically all of the services are metered.

SEWERAGE.

The sanitary sewers comprise about 25 miles of vitrified pipe sewers which range in size from 6 to 12 inches; the sewers are thoroughly underdrained for the removal of ground water. In addition to the sewers for strictly sanitary uses there have been constructed several miles of storm sewers. In some instances the storm and sanitary sewers are laid in the same trenches, and in such cases, the former are placed over the sanitary sewers, with a result that storm water leaks into the sanitary sewers and greatly increases the sewage flow. The records of the village indicate that a population of 7,000 is accessible to the sewers and that of this population, all but from 100 to 150 use the sewers for sanitary purposes.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

The sewer system was constructed in the latter part of 1899, about four years after the incorporation of East Cleveland as a village with a population of 1,000 and with no public improvements. In designing sewerage for the village it was recognized that local conditions would necessitate the thorough purification of the sewage, since only a small creek of intermittent flow was available for purposes of dilution. This creek, moreover, passes through fine residence property.

In considering the problem of sewage purification for East Cleveland conditions, it was apparent that land of a suitable character was not available for intermittent filtration and that chemical precipitation would necessitate a further finishing treatment, so that the question of sewage purification had practically to be confined to the use of artificially constructed filters. Plans in conformance with this fact were submitted to the State Board of Health in October, 1898, and provided for the purification of the sewage by filtration through sand and coke subjected to forced aeration.

Briefly described, the plant as initially proposed contained one unit with a capacity stated to be sufficient to treat 150,000 gallons of sewage in 24 hours. This unit contained six strainers, four to be operated on a down-flow and two on an up-flow basis. The sewage was to be treated next on an aerator or finishing filter of fine grain material. Aeration of the strainers and the aerators was to be effected by a fan blower which continuously admitted air for the oxidation of the organic matters. The plant was expected to produce an effluent conforming substantially to the following specifications.

It should consume practically all of its sludge without mechanical removal

or disturbance of the original deposit and without the use of chemicals. The effluent should be free from suspended organic matters, should be without color, odor or taste and should show a 90 per cent. removal of organic matter.

The State Board of Health, on reviewing the proposition, voted an approval in November, 1898, urging, however, that a satisfactory guarantee should be obtained as to results from both a chemical and bacterial standpoint, in view of the fact that the system as submitted had been in use in other places but a comparatively short time.

Shortly afterwards, the plant was constructed practically in accordance with the plans as submitted. In 1901, the rapid growth of the village necessitated an additional unit and a septic tank. This extension was necessary on account of the imperfect purification of the sewage, as shown by the polluted condition of Shaw Brook, into which the effluent was discharged. Since 1901 there have been made practically no additions to the plant, which during the present investigation has comprised substantially the following. The crude sewage pumped from a circular receiving well is discharged into a septic tank, whence it flows on to the primary and secondary filters or strainers, respectively. These are of slag and are continuously subjected to aeration by air from blowers. The sewage next flows on to the final filters or aerators constructed of sand, stone and coke. These also receive continuous aeration. The effluent flows into Shaw Brook. Conditions which will presently be discussed, led to the abandonment of this plant in August, 1907. This was made feasible by diverting a large part of the sewage to the Superior Street sewer of the city of Cleveland, and second, by connection with a 10-inch sewer of Collinwood.

EXAMINATIONS AND INSPECTIONS.

The East Cleveland sewage purification plant was visited during this investigation on eight occasions as follows: In 1906, on April 11, June 26-28 and Dec. 20; in 1907, on Feb. 11, March 22, June 27, July 10–12 and Oct. 16. Detailed examinations were made on June 26-28, 1906, and July 10-12, 1907. The other visits were inspections only.

DESCRIPTION OF PLANT.

The purification of the East Cleveland sewage is carried out on a 10-acre plot of land in the northeasterly part of the village. The site of the plant is about 600 feet from a well-traveled street and 1000 feet from a number of houses; the nearest of which is 400 feet distant. The topography of the village is such that it is necessary to pump the sewage for purposes of purification. (See Plates XXXVI. and XXXVII.)

Screening.

The crude sewage reaches the plant through two trunk sewers 24 inches and 12 inches in diameter, respectively, and flows into a circular brick pump well 20 feet in diameter and 27 feet deep, with a capacity of about 64,000 gallons. As originally planned, the sewage in discharging passes through an iron diamond mesh screen with a clear opening of ½ inch and set horizontally. The screen had an area of 157 square feet. (During 1907 the screen entirely rotted out.)

To remove screenings and sludge from the well, a bucket conveyor is provided, discharging through an inclined trough to an excavation where the deposit may be composted. Recently, 1907, a stream siphon has replaced the bucket conveyor. The screen chamber or pump well also serves the purpose of intercepting grit and the heavier matters in the crude sewage.

Pumping and Power Plant.

The sewage is raised continuously from the pump well by three centrifugal pumps. Two of the pumps have a 6-inch suction and one a 5-inch suction and all are connected to an 8-inch discharge. The ordinary lift is about 35 feet. The pumps and power plant are contained in a brick building 24x58 feet in plan. The power plant comprises two 90-H. P. horizontal tubular boilers. These provide for the operation of a 25-H. P. engine, which is connected to the centrifugal pumps and also to the blowers. These are two No. 7 Buffalo blowers, which operate at 1275 and 1315 R. P. M., respectively, each with an average discharge of 2700 cubic feet of air per minute. They are intended to supply an air pressure of 4 ounces per square inch to the hollow floor underneath the primary filters and aerators.

Septic Tanks.

Sewage from the pump well is forced by the centrifugal pumps into the septic tank. This is a brick tank with an 8-inch concrete base and walls 18 inches thick at the bottom and 12 inches thick at the top. The tank is 24x87 feet in plan, 11 feet deep on the longitudinal center line and 10 feet deep at the corners; in addition, the entire floor of the tank slopes 1 in 45. The capacity of the tank to the flow line is about 170,000 gallons. The septic tank is housed by a wooden building covered by a wooden pitched roof. There is but small head room and inspection is difficult on account of the pitch.

Inlets and Outlets. The sewage enters the septic tank at mid-depth through 11 openings 6x6 inches in plan, equally spaced across the tank. The inlet channel into which discharges the 8-inch force main from the pumps extends across the tank and is 18 inches wide and 5 feet deep.

Sewage flows from the septic tank into a "collecting box" 18 inches square in section extending across the end of the tank at mid-depth. Sewage is admitted to this box through horizontal slots 12 inches long and 2 inches wide, whence it is discharged by means of a 6-inch siphon. The outlet thus arranged is expected to afford an equal velocity throughout the cross section of the tank. The rate of flow through the tank depends entirely upon the pumping.

Measuring Weirs and Aerating Chamber. No means for measuring the sewage were originally provided, but in 1906 for the purpose of this investigation weir boxes were placed at the discharge of sewage on to each of the primary filters. No facilities for aerating the sewage are provided.

By-pass. Sewage may be pumped directly to the primary filters or to the effluent sewer by means of valves located on the 8-inch force main from the pumps. It is also possible to by-pass the septic tank by shutting down the pumps and allowing sewage to discharge through a 24-inch overflow located in the pump well.

Sludge Disposal Area.

As constructed, the septic tank contained no sludge drains nor other facilities for sludge disposal. Subsequent operation of the plant has necessitated the removal of sludge, and this is accomplished by means of a 4-inch siphon operated by a ½-inch steam jet. Sludge is discharged from the tank on to a rough excavation, where it is allowed to settle.

Primary and Secondary Filters or Strainers.

The second step in the purification of the East Cleveland sewage is accomplished by the forced aeration system, which comprises the passage of the sewage downward and upward, respectively, through strainers or primary and secondary

filters, as they were originally termed. At the present time, the primary filters are eight in number and consist of masonry tanks, each 600 square feet or 0.014 acre in area, with a total area of 0.112 acre. An 8-inch drain from the secondary and primary filters allows the tanks to be completely emptied. In such cases the sewage flows back into the pump well. The strainers proper are contained in concrete water tight basins. The primary and secondary units are supported by core walls with 4-inch sides and an open space of 8 inches, in which is built a second wall so arranged that the flow from the primary filter passes upward and over the central dividing wall, and downward on the opposite side to enter the secondary filters at the bottom. The secondary filters are constructed similarly to the primary filters and are four in number, with a total area of 0.056 acre. Two primary filters discharge on to one secondary.

Filtering Material. The filtering material is 2 feet 6 inches in depth and is composed of blast furnace slag from 1 to 3 inches in size.

Underdrains. The slag filtering material rests on an underdrain of 8-inch horse shoe tile, which in turn lies on one course of brick. This false floor covers the entire bottom of each of the primary filters. Ducts carrying the air are also caused to discharge through a system of vitrified pipes underneath the hollow floor of the primary and secondary filters.

Aerators or Sand Filters.

The final step of the purification of the sewage is carried out in so-called aerators, which are water-tight concrete basins, eight in number, 20x70 feet, or 0.031 acre in area, with a total area of 0.248 acre.

Filtering Material. The filtering material consists of separate layers of sand, pea coke and broken stone. The original specifications prescribed sand with an effective size of about 0.28 m.m. and a uniformity coefficient of 1.3. Recently (1907) resanding of the filters was effected with both lake sand and bank sand. The lake sand has an effective size of 0.35 m. m. and a uniformity coefficient of 1.5. The bank sand has an effective size of 0.18 m. m. and a uniformity coefficient of 2.7. The coke used was of the size of peas and the broken stone ranged in size from 1 to 3 inches. The depth of the sand at the present time ranges from 6 to 12 inches; the coke has a thickness of 4 feet; and the broken stone is laid in a layer 6 inches deep. The original specifications planned the successive layers of filtering material to be sand, coke and stone, respectively. Subsequent operation of the plant necessitating renewal of the sand has considerably modified these conditions. Moreover, certain of the filters now contain lake sand and others bank sand; in others, the lake and bank sand have been mixed.

Underdrains. The filtering material in the aerators also rests on a false tile floor, consisting of horse shoe tile laid on brick and covering the entire bottom. Into this false floor discharge the 8-inch air ducts. To allow the escape of air and gases, short lengths of pipe pierce the sand in the aerators and extend about 6 inches above the surface.

Dosing and Discharging Apparatus. The aerators are flooded directly from the secondary filters from a shallow concrete channel, which extends along one side of each unit. The primary filters receive the direct discharge from the siphon in the septic tank through an 8-inch line, flow from which is controlled by gate valves.

Effluent Discharge. Two uncovered concrete effluent wells located on the line of the 24-inch effluent sewer receive the purified sewage from the aerators through the 4-inch main collecting drains, one for each unit. From these two wells the effluent flows into Shaw Brook through several hundred feet of 24-inch sewer pipe. While the plant is so situated that it is not endangered by high water,

yet on account of the considerable infiltration of ground water and leakage of storm water, the flow during wet weather at times exceeds the capacity of the pumps and the sewage is by-passed through the 24-inch overflow located in the pump well.

SEWAGE FLOW.

During 1907 the quantity of crude sewage has greatly decreased, owing to provisions for disposing of the sewage of the village, as already mentioned. The sewage flow has been learned from measurements made during the two detailed examinations and also from daily observations of the flow by the weirs already described. It is to be stated that when the plant was in full operation, as was the case up to the summer of 1907, pumping was carried out continuously for 24 hours. Under dry weather conditions, two pumps were generally in service and were operated at their maximum capacity, except in the early hours of the night.

On the detailed examination of June 26-28, 1906, half-hourly measurements were made of the rate of pumping. These measurements showed an average rate of about 365,000 gallons, a maximum flow of 494,000 and a minimum of 131,000 gallons in 24 hours. On the second detailed examination the average, maximum and minimum rates of pumping were 390,000, 506,000 and 222,000 gallons, respectively. The second detailed examination was carried out during dry weather and subsequent to the connection to the Superior Street sewer.

Measurements obtained from the daily records are shown in the following table as averages by months. It is particularly to be noted that these data afford only rough information as to the quantity of sewage pumped since weir readings were generally recorded only once daily and usually in the morning. They are, however, of some value as indicating the large volume of sewage which has reached the plant during the years 1906 and 1907. Especially are they instructive as showing the effect of wet weather on the volume of sewage.

TABLE NO. 76.

Sewage Flow by Months, Daily Observations Made at the Plant.

Month.	Rate of Flow. Gallons in 24 Hours.		
	Maximum.	Minimum.	Average.
1906.			
July	549,800	187,000	395,000
August	484,300	454,800	468,000
September	499 000	369,000	449,000
October	499,300	369,000	493,000
November	615,000	439,000	527,000
December	590,000	322,000	430,000
1907.			
January	953,000	689,000	732,000
February	865,000	634,000	751,000
March	925,000	691,000	796,000
April	811,000	560,000	739,000
May	687,000	487,000	597,000
June	659,000	455,000	561,000
July	720,000	346,000	413,000
August	396,700	288,000	338,000

The average flow on the first detailed examination corresponds to 52 gallons per person tributary, a figure which compares favorably with the estimated water consumption, which in 1906 was about 56 gallons per capita. These results were obtained under strictly dry weather conditions.

Measurements on the second detailed examination gave practically similar results, but as they were obtained after a considerable part of the sewage had been diverted to the Cleveland sewers, they indicate that on this visit considerable ground water was entering the sewers. Subsequent to August 14, 1907, when connections to the Cleveland and the Collinwood sewers had both been made, the sewage flow was very low and the daily pumping period had been reduced to about three hours.

COMPOSITION OF CRUDE SEWAGE.

On each detailed examination, samples of the mixed sewage as pumped were collected at half hourly intervals for a period of 24 hours. The analysis of these samples showed that the crude sewage is of moderate strength, but is quite stale since it contains little dissolved oxygen and no nitrates. The suspended matter is fairly high but the organic matter is low, as indicated by the oxygen consumed and the organic nitrogen, features which suggest the infiltration of ground water. The analytical data obtained during this investigation follow this section of the report.

OPERATION.

The changes which have taken place at East Cleveland during this investigation have necessarily materially affected the method of operation and hence this feature will be discussed with special reference to the different procedures in use from time to time.

Until August 14, 1907, the plant was operated by four men in addition to the superintendent. One man has charge of the actual operation of the purification devices and three men on eight hour shifts have charge of the pumping, the operation of the boilers, blowers and other mechanical appurtenances. Subsequent to August 14, 1907, two men only have been employed on twelve hour shifts each.

Since the spring of 1906, for the purposes of this investigation under the supervision of the superintendent the attendant has kept daily records of certain features of operation. These have included measurements of the sewage flow, records of the labor entailed in cleaning the strainers and aerators and the septic tank and putrescibility tests of the average effluent from the aerators in service.

Pumping.

During dry weather two pumps are in use continuously for 24 hours. During storms three pumps have been used to handle the largely increased flow of sewage and at times in addition to the quantity of sewage pumped, large volumes have been by-passed. Occasionally, also, the sewage flow has increased so that pumping has been suspended and the entire volume of sewage has been by-passed.

Blowers.

The blowers are ordinarily operated continuously throughout the 24 hours, and generally both have been in service.

Cleaning of Pump Well.

During 1906, the bucket conveyor has been used from one to two times each week. The cleaning of the pump well has generally been carried out at night when

the pumps can readily remove the incoming sewage which would otherwise interfere with the process of cleaning. During wet weather, however, considerable difficulty was experienced and in the summer of 1906 it was decided to place a gate on the main sewer so that the flow of sewage could be temporarily shut off. In cleaning the pump well, the small buckets were caused to deposit the sludge into a wooden trough, about 7½ inches deep and 8 inches wide and perhaps 100 feet long, elevated above the pumping station and placed at such an angle that the liquid sludge would readily flow to the disposal area. To receive the sludge, there was prepared an excavation approximately 15x33 feet in plan and 4 feet deep. The deposit of sludge was covered with lime and allowed to remain until dry, when it has been removed from time to time by market gardeners adjacent to the plant. Considerable odor emanated from the drying sludge and occasionally complaints have been lodged against the plant on this account. The sludge is deemed to have considerable fertilizing value. When thoroughly dry it is not objectionable and has no offensive odor.

The installation of a gate on the main sewer did not prove entirely successful, and in 1907 the bucket conveyor was replaced by a 4-inch siphon or injector operated by a ½-inch steam jet. It was stated that this method of cleaning the well was found to be very satisfactory. Whatever means could be used would probably not prevent the rise of objectionable odors from the deposits of organic matter in practically a crude state as are naturally intercepted in pump wells similarly located.

Septic Tank.

Ordinarily, sewage from the pumps is discharged directly into the inlet of the septic tank, as already described, and after passing through the tank is siphoned from the outlet channel and flows on such of the primary strainers as are in service. Continuous pumping to the septic tank continued through the investigation, except when a largely increased sewage flow necessitated by-passing the tank entirely. At times the quantity of sewage delivered by the pumps could not be allowed to enter the tank, as the latter would overflow. In these cases the tank was by-passed. This was carried out for several weeks in the winter of 1907, as indicated by the daily records, and such was found to be the case on the inspection of Feb. 11, 1907. On the visit of March 22, 1907, it was again found that the sewage flow was so great that it was necessary to by-pass the septic tank, or in other words sewage was pumped directly on to the strainers. Based on the average pumpage of 365,000 gallons, as found on the first examination, the period of flow is about 10.6 hours and the corresponding linear velocity is 0.68 m.m. per sec.

Disposal of Septic Sludge.

The most interesting feature of the operation of the septic tank is the matter of sludge disposal. It is stated that the tank was cleaned in the fall of 1905 and also on one previous occasion. From the spring of 1906, the tank was cleaned on three occasions, so that during the seven years the plant has been in service up to the summer of 1907, sludge has been removed five times. Dates on which the tank was cleaned during 1906 and 1907 are as follows: October, 1906; March, 1907, and August, 1907. The quantity of sludge removed was 40, 43 and 60 cubic yards, respectively. The data are, however, too incomplete to allow of a statement of the quantity of sludge in terms of the volume of sewage treated. It is true, moreover, that large quantities of suspended matter have passed out of the tank as is suggested by the large labor item in the operation of the strainers and aerators.

Local conditions as to the design of the plant and the availability of land for disposing of the sludge have made necessary a method of disposal which re-

quired the treatment of a mixture of the sludge proper and the supernatant sewage. In cleaning the tank the East Cleveland method has been as follows: The mixture of sludge and sewage in the tank is more or less thoroughly stirred up with poles, after which the mixture of sludge and sewage is discharged by a steam ejector on to an excavation adjacent to the plant, 18x33 feet in plan and about 4 feet deep. As soon as the excavation is filled, the sludge is allowed to subside, after which operations are again continued. Arrangements are such that the supernatant liquid may flow into the pump well. After the tank has been emptied, the deposit is usually covered with a thin coating of slacked lime placed with a view to reducing odors arising from the sludge during drying. When dry, the solid residue is removed by neighboring gardeners and used for soil enrichment. In 1907, two excavations were used for the disposal of sludge. In reasonably dry weather, the sludge appears to dry rapidly and the odors arising during this process are said not to be especially objectionable. Odors from sludge at the plant have in the past arisen chiefly from the deposit of crude organic matters which have been removed from the pump well as already described.

Primary and Secondary Filters or Strainers and Aerators or Sand Filters.

The one man employed in the actual operation of the sewage purification plant, during the summer months spends nine hours a day in cleaning the strainers and aerators. Ordinarily, during the greater part of 1906, the strainers could be operated for ten days without cleaning. Up to the time considerable reduction in the dry weather sewage flow was effected by the connection with the Cleveland sewers, the strainers ordinarily have required cleaning once in four days. As ordinarily operated, sewage is diverted to a second set of strainers when those in service require cleaning. The sewage in the strainers is then discharged through the drains back into the pump well. The surface coating of sludge is allowed to dry somewhat, after which it is removed. The surface of the actual filtering material is then washed with water from a hose and the filter is allowed to remain idle under full air pressure from the blowers.

Ordinarily in the drier months, two or three primary strainers are in service. Under the increased flow obtaining during the spring of 1907, at times as many as five strainers have been required to handle the flow of sewage. In this last case, of course, the pumps were discharging directly on to the strainers.

The operation of the aerators or sand filters has corresponded to that of the strainers in accordance with the design which provides that each set of strainers shall be used in connection with one aerator. Ordinarily, the effluent from the strainers has been further treated on the aerators, but during the winter of 1907 such heavy clogging was in evidence that it was necessary to by-pass the aerators, as was found to be the case on the inspection of Feb. 11, 1906.

In common with the strainers, the sand filters required frequent cleaning and in fact the clogging of the aerators became so serious that in the spring of 1907, acting on suggestions made by the State Board of Health, layers of clogged sand were removed. Under conditions obtaining in the summer of 1906, the sand filters are stated to operate for from four to five days before cleaning is necessary; later, however, the clogging was so severe that the sewage could not be passed through the aerators without serious clogging for more than one or two days. In cleaning the filters the sewage is shut off and the surfaces are allowed to dry. This operation requires from two to three days, depending upon the weather and the extent of drying. The deposit curls up when dry and is readily removed. The filter surface is then raked lightly and clean sand is put on approximately equal in quantity to one-half the sand and suspended matters removed by scraping. At times the filters are forked to a depth of 6 inches but no sand is placed upon them.

The resanding of the aerators was suggested on the inspections of Dec. 20, 1906, and Feb. 11, 1907, on account of the serious clogging and the low efficiency of the plant. Finally in March, the clogged sand was removed from five of the filters and in its place was deposited 54 cubic yards of bank sand and 24 cubic yards of lake sand, the mechanical analysis of which has already been stated. The resanding of the aerators for a time improved their operation, but the largely increased sewage flow again caused a rapid clogging and up to the abandonment of the purification of the East Cleveland sewage, the filters were operated with increasing difficulty due to the clogging of the finer surface material. It is to be understood, of course, that the application of air to the strainers and aerators is carried out continuously not only during resting periods but also when these devices are in full operation. Even this provision has not prevented serious clogging necessitating a vast quantity of labor in maintaining the plant in serviceable condition. Some conception of the labor involved in the actual operation of the strainers and aerators at this plant, during the year 1906, and the nine months of 1907, may be obtained from the following table, which summarizes the operation data obtained from the daily records:

TABLE NO. 77.

Record of Operation—July, 1906, to August, 1907, Inclusive.

Month.	Strainer.* Days.	Labor Required in Operation of Plant. Total Days, 1 Man 9 Hours Per Day.	
		Strainers.	Aerators.
1906.			
July	62	12	19
August	62	15	16
September	60	9	21
October	60	9	16
November	76	8	22
December	79	3	28
1907.			
January	101	2	29
February	112	6	24
March	109	5	21
April	119	7	23
May	93	4	27
June	95	5	25
July	91	5	26
August†	42	4	10

* Equivalent days for operation of one strainer only.

† To August 14.

RATES OF FILTRATION.

The average approximate rate of pumpage from July, 1906, to August, 1907, ranged from 338,000 to 796,000 gallons in 24 hours. On this basis, the rates at which the primary and secondary strainers and aerators have been operated are, respectively, 3,100,000 to 7,100,000, 6,200,000 to 14 200,000 and 1,360,000 to 3,200,000 gallons per acre in 24 hours. The combined area of strainers corresponds to 42,000 persons per acre; that of the aerators corresponds to 28,000 persons per acre.

These exceedingly high rates and the heavy population loads per acre suggest the impracticability of the East Cleveland plant to afford a satisfactory purification of the village sewage in recent years, due to the rapid growth of the town.

EFFICIENCY.

The efficiency of this plant was first studied shortly after it was first placed in service. In view of an alleged nuisance from the effluent, the State Board of Health on an examination in March, 1901, found the plant overworked and not producing a satisfactory effluent and on this account the plant was subsequently enlarged as already described. The purification effected by the plant continued satisfactory for some time, but in 1903 an inspection made by the State Board of Health indicated only a fair resulting purification of the sewage of the village.

Since the year 1903, the population of the village has been rapidly increasing and with it the quantity of sewage. Somewhat in the same measure the efficiency of the plant has gradually fallen off, as the capacity of even the enlarged plant has gradually been exceeded.

The preliminary inspection of the plant in April, 1906, gave the first evidence during this investigation that the capacity of the plant had been reached, for it was found that the effluent from the aerators was ill-smelling and putrescent. So much sewage was reaching the plant that the pumps could not handle the entire flow and considerable crude sewage was discharged into the effluent sewer.

The analytical data obtained upon the first detailed examination in June, 1906, confirmed the conclusions drawn from the inspection in April. It was developed that the plant was capable of effecting a fair purification of the sewage only under extremely dry weather conditions. In this connection it will be recalled that the plant as enlarged to two units was intended to furnish a satisfactory purification of the sewage at a rate of 300,000 gallons per day. At this time, the sewage flow was decidedly in excess of this figure even in dry weather, and the attempt to treat the still larger flow during wet weather, had greatly increased the labor involved in maintaining the plant so that when the normal flow reached the plant, the heavy clogging of the strainers and aerators prevented the proper purification of even that quantity of sewage which the plant could reasonably be expected to handle satisfactorily. Certain interesting data were learned at this detailed examination and it is of interest to record some of them briefly.

Samples were collected during the examination of the effluent of the septic tank. In comparing the analytical data with those of the weighted analysis of the crude sewage (see p. 592), it will be noted that the septic effluent contained 399 parts per million of suspended matter as against 224 parts per million in the case of the crude sewage, or in other words, the increased flow of sewage caused certain of the suspended matters previously deposited to be discharged from the tank. An inspection of the tank showed that there was actually a small accumulation in spite of the somewhat long period of service since the tank was last cleaned. The condition of the effluent with respect to suspended matter and the frequent obligatory cleanings of the strainers and the aerators, in a practical way suggested that the septic tank was very inefficient in the preparatory treatment of the crude sewage. As computed from the average sewage flow, the period of flow into the tank was about 11.2 hours.

The effluent from the final filters was on this examination black in color and was not purified sufficiently to afford a stable effluent. The analytical data appended will indicate this to be the case.

Evidence obtained on the three subsequent visits up to the detailed examination in July, 1907, in general indicated that the plant was overworked and that its efficiency was very low. Of special interest is the clogging of the sand in the

aerators as noted on the visit in December, 1906. On analysis, sand from the center of the filters was found to contain organic and clogging material as follows: Organic nitrogen. 7,000; loss on ignition, 27,000; and ether-soluble matter 15,000 parts per million; that from the side of the filters showed 9,000, 54,000 and 15,000 parts per million of these constitutents, respectively. The desirability of resanding the filters was therefore strongly indicated. The inspection of Feb. 11, 1907, again showed the general condition of the plant to be poor by virtue of the largely increased sewage flow. On the following inspection, it was found that the filters had been resanded and that the operation of the plant had been somewhat improved in consequence. The final effluent continued to be putrescible, however, as shown by the daily putrescibility tests. Before the second detailed examination was carried out, connection had been made with the Superior Street sewer of the city of Cleveland. Even in view of this fact, the average rate of pumping, as before stated, was 390,000 gallons per day, a figure still 90,000 gallons in excess of that for which the plant was designed.

This detailed examination indicated that there had been a decided improvement in the efficiency of the plant and that the effluent was non-putrescible. Interesting data were obtained as indicating in a general way the effect of the forced aeration on the oxygenation of the sewage in its passage through the plant. These dissolved oxygen data are tabulated in Table No. 78. It is noticeable that only the effluent from the aerators or final filters contains dissolved oxygen. As reference to the appended analytical data will indicate, the dissolved oxygen introduced in the aerators oxidized sufficient nitrogen to produce a stable effluent. On all previous occasions, serious clogging and a heavy flow of sewage had practically prevented the successful aeration and nitrification of the final effluent.

TABLE NO. 78.

Aeration of the Crude and Septic Sewages, Respectively, and the Effluents from the Strainers and Aerators.

July 10-12, 1907.	Parts Per Million. Dissolved Oxygen.			
	Crude Sewage.	Septic Sewage.	Strainer Effluent.	Aerator Effluent.
12:00 Mid.	0.2	.....	.....	.....
4:00 A. M.	0.2	.....	.....	.....
8:00 A. M.	0.1	0.0	.....	.....
12:00 Noon	0.04	0.0	0.04	6.8
4:00 P. M.	0.0	0.0	0.0	6.7
8:00 P. M.	0.0	0.0	0.0	2.4
12:00 Mid.	.....	0.0	0.0	3.6
4:00 A. M.	.....	0.0	0.0	4.0
8:00 A. M.	.....	.....	0.0	5.6

It is of further interest to note from the analytical data that the septic effluent was again found to contain more suspended matter than the crude sewage, although the tank had been cleaned in June, 1907. Conditions in the tank were apparently such that in view of the active fermentation in the sludge, the suspended

matters forced to the surface do not subside, but are carried on to the strainers and in part to the aerators and cause serious clogging.

SUMMARY.

The results of this investigation show that the efficiency of the East Cleveland plant has been low on account of an increase in the sewage flow of the village to such an extent that even under constant care, the strainers and final filters became so clogged with organic matter that even the feature of forced aeration was not able to oxidize the organic matters and allow the production of a stable effluent. Available data suggest that the application of air in accordance with the fundamental principle of the forced aeration process, does not suffice to oxidize the accumulating organic matters with sufficient thoroughness. It seems to be clear, however, that with sufficient attention the plant as it has existed during the investigation, can purify to the point of ultimate stability about 300,000 gallons of sewage in 24 hours.

Although the diversion of a considerable part of sewage of the village to the Cleveland sewers decidedly improved the condition of the plant, yet had not there been made the connection with the Collinwood sewers it is probable that there would have been necessary an enlargement of the present plant were the sewage of the village to be treated in the future without nuisance. The Collinwood connection, completed on Aug. 14, 1907, practically effected the abandonment of the plant in regard to the purification of the sewage of the village of East Cleveland, for since that date no purification of sewage has been attempted and the small quantity of daily pumping is confined to pumping from the well a small volume of sewage which can not flow by gravity to either the Cleveland or Collinwood sewers.

COSTS.

The cost of the plant was $56,292, divided as follows:

Land	$12,500
Pump well, machinery and first unit	20,700
Septic tank, second unit and boiler	17,900
Engineering and patent rights	5,192
Total	$56,292

The operating costs have increased from year to year as would naturally be expected in view of the increasing flow of sewage. The operating costs for 1906, according to information obtained from the superintendent, were $6,226.87 and for the first nine months of 1907 were $5,287.45. For the remainder of 1907, the cost of operation was at the rate of $3.00 per day each for two men, or $552, or a total cost for 1907 of $5,839.45. The cost per month during 1906 was about $520, and for the nine months operation in 1907 was about $590. The operating costs per annum on the basis of the 7,000 persons tributary to the plant was in 1906 about 90 cents, and in 1907, 76 cents. These high per capita costs are, of course, in part to be explained by the necessity for pumping the entire sewage flow of the village, but are also due to the large amount of labor entailed in the operation of the plant, especially the frequent cleaning of the strainers, aerators, septic tank and pump well.

It is interesting to compare the costs of operation of the years 1906 and 1907 with corresponding data for the year 1903, as shown in the special sewage report of the State Board of Health for that year. The annual operating costs, excluding

capital charges, were in 1903, $2,980, or on a per capita basis, about 60 cents per annum. The large increase in the per capita cost of operation is clearly indicated by these data.

Details of the operating costs for the years 1903, 1906 and 1907 are shown in the following table and in each case the data represent actual operating costs exclusive of interest and depreciation.

TABLE NO. 79.

Detail Costs of Operation.

	1903.	1906.	1907.
Labor*	$1,980 00	$3,943 12	$3,185 51
Coal	700 00	1,445 36	973 08
Supplies and repairs	300 00	838 39	1,128 86
Labor, October to December, 1907, 2 men at $3.00 per day	.....	.....	552 00
	$2,980 00	$6,226 87	$5,839 45

* 1903 two stationary engineers, one extra laborer; 1906 three stationary engineers, one extra laborer and occasional additional assistance.

No separate items were made of the cost of sludge disposal and unfortunately no data on this point are available.

The estimated population tributary to the plant in 1903 was 5,000.

TABLE NO. 80.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts per Million.														Remarks.
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspend'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.	
					Organic		Free Ammonia.	Nitrites.	Nitrates.								
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.					
							Crude Sewage.										
June 26-27, 1906..	12:00 P.- 6:30 A.	57	35	17	4.2	2.1	10.0	0.06	0.0	37	134	83	48	0.0	....	74	
June 27, 1906.....	7:00 A.-11:30 P.	59	63	31	22.0	8.8	9.6	0.00	0.0	59	242	162	40	0.0	....	115	
Weighted Av'ge.	.....	58	55	27	17.1	7.1	9.7	0.02	0.0	53	213	141	42	0.0	....	104	
July 10-11, 1907...	12:00 P.- 7:30 A.	59	23	10	2.4	0.8	9.6	0.00	0.0	38	141	71	60	0.2	....	31	
July 11, 1907.....	8:00 A.-11:30 P.	60	23	15	10.4	3.2	13.6	0.12	0.0	61	98	68	61	0.0	....	53	
Weighted Av'ge.		60	23	13	7.7	2.4	12.3	0.04	0.0	53	112	69	61	0.1	....	46	
							Effluent Septic Tank.										
June 27-28, 1906..	8:00 A.- 7:30 A.	59	96	31	25.1	8.8	12.5	0.00	0.0	58	399	238	50	0.0	....	110	
July 11-12, 1907..	8:00 A.- 7:30 A.	60	18	....	10.7	.....	12.5	0.07	0.0	.....	179	102	....	0.0	....	....	
							Effluent Strainers.										
July 11-12, 1907..	9:00 A.- 8:30 A.	61	26	....	5.0	.....	12.8	0.05	0.0	.....	100	60	....	0.0	+	....	

Effluent Aerators.

June 27-28, 1906.	10:00 A.- 9:30 A.	63	24	....	13.5	.....	5.6	0.35	3.0	.....	69	39	....	3.8	+	....	East Well
June 27-28, 1906.	10:00 A.- 9:30 A.	63	29	....	14.4	.....	6.0	0.40	8.0	.....	83	33	....	3.8	+	....	West Well
July 11-12, 1907.	10:00 A.- 9:30 A.	63	12	....	0.8	.....	5.6	0.12	6.6	.....	57	40	....	4.9	+	....	Strong odor

KENTON, NORTH DISTRICT.

The city of Kenton, the county seat, is in the central part of Hardin County, principally on the watershed of the Scioto River. On account of local topography, however, the North District of the city, which has an area of about 150 acres, drains naturally northward into a county ditch which leads into a tributary of the Maumee River. As exterpolated from the census reports, the present total population of the city is 7,000.

Considerable manufacturing is carried out in Kenton and the city is in the center of an extended territory devoted to agricultural pursuits. A number of municipal improvements have been carried out including a public water supply, a system of sanitary and storm sewers, respectively, and about 5.2 miles of paved streets. The water supply of the city was installed in the year 1883 and is obtained from driven wells, which in 1906, according to the records of the water department, supply daily 759,000 gallons.

The main portion of the city which drains into the Scioto River is provided with an extensive system of sanitary and storm sewers. The sewage from this district discharges into the Scioto River without treatment. Sewage from the North District of the city could not be discharged by gravity into the main sewer system of Kenton in view of topographical conditions, and hence it was necessary to provide a separate means for the sewering and for the disposal of the sewage of this district.

SEWERAGE OF THE NORTH DISTRICT.

In the year 1900 sanitary sewers were constructed for the North District which is exclusively residential. The sanitary sewers comprise about 6 miles of pipe sewers which range in size from 8 to 12 inches. The system is provided with 11 flush tanks. The sanitary sewage is conducted to one point where it is purified. According to local records, the North Kenton District has a population of 400 persons, all of whom are connected to the sewers for sanitary purposes. The district has been considerably improved and contains 3.8 miles of paved streets. Provisions for the removal of storm water from the streets was made by the construction of about ¾ mile of storm sewers. Up to the summer of 1907, however, considerable storm water has been carried off by the sanitary sewers.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In considering the problem of providing sewers for the North District, it was appreciated that the natural outlet was the county ditch, which has practically a dry stream bed in the summer months. To prevent a nuisance which would undoubtedly be caused unless the purification of the sewage was undertaken, plans for this purpose were prepared simultaneously with those for the sewering of the district. These plans were presented to the State Board of Health in June, 1900, and were approved subject to any change the Board might see fit to require after a fair trial of the plant. The plant for the treatment of the sewage of this district was constructed in 1901. It comprises the treatment of the sewage in septic tanks, followed by oxidation in so-called wave filters constructed of coarse grain material to which the sewage is applied by specially constructed dosing filters, each of which is discharged by a siphon.

Kenton. — General View of Plant. Effluent is Collected in Channel Running Across Lower End of Filters.

Kenton. — Septic Tanks, Dosing Filters and Siphons Which Discharge at Upper End of Wave Filters.

EXAMINATIONS AND INSPECTIONS.

This plant was visited six times. Detailed examinations were made on October 5th, 1906, and July 23d, 1907. Inspections were made on March 31st, 1906, and in 1907 on March 13th, May 15th and October 25th.

DESCRIPTION OF PLANT.

The sewage plant for the North Kenton District occupies 0.5 acre of land located about one mile from the corporation line, and about one-quarter mile from the nearest house. (See Plate XXXVIII.)

Septic Tanks.

The sewage from the 12-inch main sewer flows directly into two septic tanks, each 7 feet 6 inches x 28 feet in plan and 7 feet deep, with an average depth to the flow line of 6 feet. The capacity of each tank is 9,400 gallons and the total capacity to the flow line of the two tanks is 18,800 gallons. The tanks are constructed of brick and concrete. The walls are of 13-inch brick and the central dividing wall of brick consists of three courses, 17, 13 and 8 inches thick, respectively. The bottom is of concrete 6 to 8 inches in thickness. The tanks are housed with a wooden pitched roof which affords a head room of only 3 feet 6 inches on the center line and therefore renders inspection difficult. There is a small entrance to the tanks through a door at the outlet end of the tank, thus providing to a certain extent for ventilation.

Inlets and Outlets. Sewage enters the tanks through 8-inch elbows which are turned downward and enter each tank 3 feet below the flow line. The outlet of each tank consists of a 6-inch opening which leads into a wooden channel thence through a 6-inch spillway to the dosing filters. The outlets are located 3 feet below the flow line of the tanks.

Baffles. A submerged 6-inch brick wall extends from the bottom of the tanks to a point 4 feet below the flow line and 3 feet from the inlet, and serves as a baffle to still the incoming sewage.

Sludge Drains. The floors of the tanks slope 6 inches to the longitudinal center line. At the outlet of each tank there is a 5-inch drain to be used for the removal of sludge and the emptying of the tank when required.

Method of Control. The discharge from either of the tanks may be cut off completely by means of a 6-inch rubber seated tompon gate. There are no other means for controlling the rate of flow through the tanks and this feature depends upon the sewage flow. Either one or both tanks may be used as desired.

By-pass. A 5-inch pipe at the outlet end of the tank leads to a sewer on the north side of the plant and discharges into the effluent channel at the toe of the wave filters, and serves as a means for by-passing the sewage after subsidence in the septic tanks. A spillway at the inlet end of the tank allows the by-passing of excess flows into a sewer which leads to the effluent sewer.

Aerating Channel and Measuring Weirs. The septic sewage receives no aeration, but passes directly to the dosing filters. Under this arrangement no means are available for measuring the rate of sewage flow.

Sludge Disposal Area.

No permanent area was designed for disposing of sludge should it ever be necessary to clean the septic tanks. A small strip of land adjacent to the wave filters could probably be used for this purpose.

Dosing Filters or Strainers.

Sewage from the septic tanks flows into the dosing filters or strainers. These are three in number, one for each wave filter and are 5x10 feet in plan and 2 feet deep. They are filled with broken stone of from 1 to 2 inches in size. The sewage passing upward through an 8-inch pipe discharges about 3 inches below the surface of the stone in these flushing filters. When the latter are filled to a given height, the sewage is discharged by a 10-inch siphon.

Filters.

The sewage discharging in doses from the flushing filters passes for final treatment onto what are called wave filters. These filters are three in number, each 10 feet wide, 100 feet long with an area of 1,000 square feet, or a total area of 3,000 square feet, or 0.069 acre. The filters are surrounded with brick walls and the individual units are separated by low brick walls about 12 inches high.

Filtering Material. The filtering material consists of broken stone and pea coke. The broken stone ranges in size from 1 to 3 inches. The coke is broken to the size of peas. The depth of the filtering material ranges from 2 feet at the upper end of the filter to 6 inches at the toe. Originally the stone and coke were carefully separated but subsequent operation of the plant has caused them to be intermixed.

Underdrains. The filtering material rests on a concrete apron 2 inches thick. No underdrains are provided. This apron is 100 feet long and slopes 4 feet per 100.

Dosing and Distribution Devices. The dosing filters provide for the periodic discharge of a considerable volume of sewage at the high point of each wave filter. At this point, there is constructed what is termed a head bay, which is merely an apron of concrete placed for the purpose of forming a head of sewage, thus permitting the discharge of the sewage onto the filters in the form of a wave. The sewage passing in waves down to the toe of the filters, flows through a number of 2x8½-inch openings in an 8½-inch brick toe wall located at the foot of the slope onto a channel of semi-circular cross-section which leads to a county ditch about 200 feet distant.

Effluent Discharge. The effluent flows from the filters by gravity, and as there is no danger of floods, no special provisions are made for the protec ion of the outlet.

SEWAGE FLOW.

On the first detailed examination, the flow of the effluent from the wave filters was weired and on the second, there was kept a record of the number of discharges of the dosing siphon. In gaging the effluent flow, a number of five minute readings were taken to allow for the wave effect. In the case of the dosing filters, the voids were considered to be 33 per cent. Both series of measurements were carried out from 6:00 o'clock a. m. to 10:00 o'clock p. m. under dry weather conditions. The rate of sewage flow for 24 hours on the two detailed examinations was 19,000 and 17,000 gallons, respectively. There is practically no flow after 10:00 o'clock p. m. during dry weather, and hence the total flow per day was only 13,000 and 11,000 gallons on the two examinations, or 32 and 27 gallons per person tributary, respectively. During the second examination the two dosing filters in service collectively discharged 67 times.

The sewage flow during wet weather is of special interest at this plant as it has had such a marked effect on its efficiency. During 1906. large volumes

of storm and ground water have reached the plant. The actual volume of discharge during storms is not known definitely, but an inspection in March indicated by rough measurements that at that time the flow was at the rate of 260,000 gallons in 24 hours, or fully ten times the strictly normal flow of the plant. In the late spring of 1907, a break was located and was subsequently repaired. Since that time, the volume of storm water reaching the Kenton plant has been greatly diminished, although it appears that some still continues to flow into the supposedly strictly sanitary sewers of the district.

COMPOSITION OF CRUDE SEWAGE.

The character of the sewage of the district is, of course, strictly domestic. On the two detailed examinations samples of the crude sewage have been collected for periods of 16 hours and these have indicated the general character of the sewage. On October 5th, 1906, there were no nitrites, nitrates, nor dissolved oxygen, but on the examination of July 23, 1907, again under dry weather conditions, the sewage contained dissolved oxygen and high nitrogen as nitrites and 1.0 part per million of nitrogen as nitrates. The suspended matters on the first examination were unusually high and it is, of course, probable that during storms prior to the summer of 1907, large quantities of clay and sand have been carried by the crude sewage.

OPERATION.

The operation of the North District sewage purification plant is in charge of the superintendent of the waterworks. Under his supervision one laborer is employed about one day per week. His duty consists chiefly in cleaning and raking the filtering material. The operation of the plant is in general essentially automatic.

Septic Tanks.

As operated, the crude sewage flows by gravity into tne septic tanks, both of which have been used at the same time. Under dry weather flow conditions, the period of flow is about 36 hours with two tanks in service. The accumulation of the sludge, however, had in the summer of 1907, so reduced the capacity of the tank that the period of flow was only about 19 hours, and the linear velocity was 0.14 m. m. per second. The tanks have not been by-passed during this investigation except automatically by the device constructed to serve as an overflow. To the close of this investigation the tank had never been cleaned. The attention necessary in operating the septic tank is practically confined to a change in the outlet which is effected by means of the tompon gate. This change is made when it is desired to rest any one of the three wave filters.

Dosing Filters.

The dosing filters have required considerable attention on account of clogging. Prior to the spring of 1906, the screen originally provided to protect the upper end of the discharge pipe from the septic tanks was removed and was replaced with coarse stone. The half-inch screen on the lower end was still in use but clogged very frequently and required the complete removal of the filtering material about once in three months. To avoid this feature, at the first visit during this investigation, it was suggested that the screen be removed and that it be replaced with an underdrain composed of coarse stone. This suggestion was ultimately carried out.

Clogging of the dosing filters still continued at frequent intervals, and it has been necessary to remove the upper layers of the broken stone filtering material in the dosing filters at about weekly intervals. Ordinarily, two of the dosing filters are in service, but in wet weather all three are used. In dry weather the sewage flow is not sufficient to cause more than two siphons to operate normally. The high flow incidental to the wet weather of the spring of 1907, generally necessitated the operation of all three of the dosing filters.

The frequent clogging of the dosing filters suggested that it might be possible to remove the filtering material so that the filters would act merely as dosing tanks. This expedient was attempted in June of 1907, but it was found that the dose of 750 gallons was so large that the wave in its entirety passed from the head bay to the toe of the filters, or in other words, that a part of the dose would flow into the effluent drain unpurified. As this practice could not of course be permitted, filtering material was again placed in the dosing filters.

Wave Filters.

The flooding of the wave filters is, of course, effected by the dosing filters. Weather conditions, especially the large sewage flow already described, have materially affected the operation of these devices. Aside from raking and cleaning, practically no attention has been necessary in the operation of the wave filters. While during wet weather all three have been in service with wave-intervals as low as 5 minutes, yet during dry weather the rate of sewage flow is so low that only two wave filters can be used at one time. In 1907, it was suggested that the filters in service be changed at weekly intervals, and such is stated to be the present method of operation.

On the preliminary inspection of the plant it was stated that the wave filters were cleaned twice a year. During this investigation this practice has still continued. The material is shoveled onto land adjacent to the filters, then spread out in thin layers, and from time to time is forked. This exposure to the sun, wind and rain, suffices to restore the filtering material so that after screening through a one-fourth-inch screen to remove adhering dirt it is again available for use when it is necessary to replace the coke and stone in the wave filters. Based on the average dry weather sewage flow of 12,000 gallons in 16 hours, the rate of operation with two wave filters in service is 390,000 gallons per acre per day; or a net rate for the entire plant of 260 000 gallons per acre per day. The wet weather rate has, of course, been very much higher. The population tributary per acre is 5,800.

EFFICIENCY.

The relation of the several parts of the plant to its efficiency and the general results obtained are next discussed.

Septic Tanks.

On the examinations of this plant made prior to this investigation, it was found that the septic tanks were apparently very efficient in destroying sludge, since after nearly 1½ years operation, there was found only about 12 inches of sludge. On the first examination during the investigation, the suspended matters in the crude sewage were very high and in the septic effluent were reduced from 224 to 176, a removal of 21 per cent.; on the second examination, the percentage removal was negative and the effluent from the septic tanks carried 122 parts of suspended matter, while that of the crude sewage was only 72.

The presence of such large quantities of suspended matters in the effluent from the septic tanks shows that suspended matters previously deposited were being carried out of the tank with the effluent. Early investigations of the plant have shown practically little sludge, but measurements made on the first examination showed that the tanks contained about 28 cubic yards, or about 30 per cent. of their total capacity. The second detailed examination in July, 1907, showed that there was a large increase in the quantity of sludge held in the tanks since the measurements made on October 5th, 1906, as it was then found that about 50 per cent. of the capacity of the tank was sludge. Moreover, the sludge was in such a large quantity as almost to clog the inlets. This condition of the tanks suggested the necessity for cleaning in the near future and a suggestion in regard to this matter was informally made to the official in charge of the plant.

In the removal of suspended matter, the tanks have not been efficient. With the low dry weather flow and the long period of service, it would naturally be expected that the removal of suspended matter would be high. Conditions in the tanks, however, are such that fermentation is active and the result is a constant movement of sludge back and forth from the bottom to the top and in the event of rain, no doubt, considerable material is discharged onto the dosing filters. During this investigation, and in fact since the plant was built, no scum has formed on the surface of the septic tanks and no objectionable odors have been noted, although the period of flow is very long in dry weather.

The tests for dissolved oxygen were negative on the first examination, but on the examination of July 23, 1907, the crude sewage was more dilute and dissolved oxygen was found both in the crude sewage and in the effluent from the septic tanks as shown in the following table:

TABLE NO. 81.

Dissolved Oxygen in the Crude Sewage and in the Effluent of the Septic Tanks on July 23, 1907.

Hour.	Temperature Degrees F.		Dissolved Oxygen. Parts Per Million.	
	Sew.	Eff.	Sew.	Eff.
8:00 A. M.	62	63	3.8	1.6
12:00 Noon	64	63	2.7	0.0
4:00 P. M.	65	64	3.9	0.7
8:00 P. M.	63	62	3.5	1.3
Average	64	63	3.5	0.9

NOTE: It is of interest to note that dissolved oxygen persists in the effluent of the septic tanks, although the period of retention is somewhat prolonged.

DOSING AND WAVE FILTERS.

Aside from the feature of storing sewage to form the wave, the dosing filters were expected to remove a part of the suspended matter from the septic sewage. The dosing filters were so clogged and such large quantities of suspended matter were periodically discharged from them that no separate samples

were collected from these filters during this investigation. Inspection alone was sufficient to indicate that while they serve to remove some suspended matter, as is also indicated by the frequent necessity of removing clogged filtering material, yet the general clogged appearance of the wave filters and the high suspended matter in the effluent from the dosing filters, suggests that the efficiency of these strainers is not high. The labor entailed in their operation is not commensurate with the benefits derived from their use, but were the filtering material removed, as was tried in the spring of 1907, the dose would give too large a wave and some sewage would reach the effluent drain unpurified.

The success of the wave filters according to the designers, depends upon the formation of a head of sewage at the upper end of the impervious apron which supports the filtering material. It is assumed that this wave continues as such until it reaches the collecting drain at the toe of the slope. One of its principal offices is stated to be the displacement of the carbonic acid and nitrogen gas which are formed in the pores of the filtering material during a period of rest and the introducing of a fresh supply of oxygen. In purifying the sewage it was claimed that the effluent would be thoroughly aerated, well nitrified and non-putrescible at all times.

The history of the plant since its construction in 1901 and especially as found during this investigation has shown this not to be the case. Since constructed it has been examined by the State Board of Health five times and inspected on three occasions. With the exception of the year 1895, it has been examined each year. On the first examination made in March, 1902, it was found that the effluent was satisfactory and that it contained nitrates and dissolved oxygen sufficient to render it non-putrescible. An examination reported in the special report of the State Board of Health for 1903 showed that the removal of organic matter effected by the plant was low, that the effluent was not nitrified and was unsatisfactory. Similar results were obtained in September, 1904.

The first detailed examination during this investigation indicated that the effluent was not so highly purified as was anticipated, but that there were no odors from the plant and that the purification of the sewage was being effected without nuisance. Developments throughout the investigation up to the time the second detailed examination was made on July 23d, 1907, indicated that the efficiency of the plant was related to the admission into the sanitary sewers of large volumes of ground and storm water. The largely augmented sewage flow during wet weather tended to scour sludge from the septic tanks, greatly clogged the dosing filters and caused them to discharge at times continuously so that there was no opportunity for air to enter the filtering material between successive waves. It was brought out that the plant was least efficient after an extended period of wet weather especially in the spring.

The matter of the entrance of storm water into the sanitary sewers was finally taken up in the spring of 1907 in view of the construction of a land drain by the commissioners of Hardin County. It was proposed to allow the effluent from the North District sewage plant to enter this drain, but residents below the plant objected on the grounds of a nuisance. The matter was investigated by the State Board of Health, and the County officials were advised to take steps to remove the storm water from the sanitary sewers, as evidence available from this investigation had strongly indicated the possibility that the plant could successfully be operated, provided it should receive the dry weather sewage flow only. The entrance of a certain volume of storm water was then prevented, as before stated, and this fact together with a period of dry weather, shortly following this advice to the city officials, created a marked improvement in the plant as was found on the second detailed examination made on July 23d, 1907.

It was then noted that the effluent was non-putrescible, nitrified in part and in part aerated. Since the examination made under a low sewage flow shortly after the plant was in service, this was the first examination which had shown a satisfactory effluent.

SUMMARY.

While the purification of the sewage of the North Kenton District has been accomplished by the wave filters without nuisance, yet the efficiency of the process has at times been low and is by no means so great as claimed for this type of sewage filter. Storm and ground water have combined to interfere with the normal operation of the wave filters and have no doubt materially influenced the clogging of the filtering material. The semi-annual renewal of the stone and coke on a dry weather flow basis has corresponded to a removal of filtering material of 41 cubic yards per million gallons of sewage treated.

The septic tanks have not been efficient in the removal of suspended matter and should be cleaned in the near future.

COSTS.

The cost of the wave filter plant was about $4,000.

The operating costs of the sewage purification plant were $116 for the year 1906 and $106 for the year 1907. They comprise annually the labor of one man one day per week at $2.00 per day. This labor is sufficient to clean and renew the filtering material and maintain the plant in satisfactory condition. Very little supervision is entailed on the part of the superintendent of the waterworks, who is in charge of the operation of the plant. No cost records are available as to the cleaning and renewal of the filtering material. The items of expense other than labor were in 1906, $12 for 10½ cubic yards of broken stone and in 1907, $2 for repairing one of the siphon heads. The annual costs for 1906 and 1907 were 29 and 26 cents per person tributary.

TABLE NO. 82.

Result of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts per Million.														Remarks.
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspend'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats	
					Organic		Free Ammonia.	Nitrites.	Nitrates.								
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.					
Crude Sewage.																	
Oct. 5, '06	9:00 A.- 8:30 P.	62	53	.....	8.0	4.4	11.0	0.00	0.0	53	224	136	....	.....	....	67	Air temp. 69°
July 23, '07	6:00 A.-10:00 P.	64	8.6	.....	10.4	5.4	6.6	1.20	1.0	48	72	38	50	3.5	....	....	
Effluent Septic Tanks.																	
Oct. 5, '06	8:30 A.- 8:30 P.	62	35	.....	7.2	4.0	11.0	0.00	0.0	46	176	98	....	.....	....	....	
July 23, '07	6:00 A.-10:00 P.	63	5	.....	10.2	.....	6.8	1.50	0.0	....	122	54	....	0.9	....	....	
Effluent Wave Filters.																	
Oct. 5, '06	8:00 A.- 8:00 P.	64	30	.....	4.2	.....	10.0	0.00	0.0	43	98	.....	....	1.7	+	....	
July 23, '07	7:00 A.-10:00 P.	70	6	.....	5.3	.....	6.7	0.34	1.0	....	54	32	....	3.3	0	....	

See fly leaf for Municipal Plants.

INSTITUTIONAL PLANTS

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FAIRMOUNT CHILDREN'S HOME, ALLIANCE.

The Fairmount Children's Home, maintained jointly by Stark and Columbiana counties, is four miles south of the city of Alliance, on land which drains into a small ditch which subsequently enters the Mahoning river above the intake of the Alliance waterworks. The Home has a population of 150, of which the greater part are young children. A water supply was installed in 1886 and is derived from a driven well, from which water is obtained by a wind mill supplemented by steam power. The daily water consumption, estimated from the records of the discharges of the dosing tank, a part of the present sewer system of the Home, averages about 15,000 gallons daily.

Prior to 1896, small defective drains served to carry off the sanitary wastes of the institution, but since that date an efficient and modern sewer system has been in use. This, the present system, comprises 6-inch gravity sewers of vitrified pipe. These are connected to all the buildings and lead to a manhole where the sewage is screened and from which the sewage flows into an 8-inch sewer laid on an 1 per cent. grade to a storage or dosing tank, discharged by alternating siphons.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In 1895, as a result of a visit of inspection to the Home by the Stark County Visiting Board, formal complaint was made to the Ohio State Board of Health in regard to a nuisance caused by the absence of proper sewerage facilities for the institution. A committee appointed by the Board to investigate, reported that the sewers at the institution were in very poor condition, and that the small brook adjacent to the Home, during freshets caused serious nuisance to farmers by virtue of its foul condition caused by pollution by the sewage of the Home, and tended to endanger the water supply of the city of Alliance. The committee recommended that the county commissioners of Stark and Columbiana counties take speedy measures to remedy these defects. It was further recommended that a sanitary engineer be retained and that the sewage be purified before being admitted into the run adjacent to the institution. About one year later a sewage purification plant was constructed and comprised a sub-surface system of sewage disposal. This system after two years' use proved a failure on account of the clogging of the distribution pipes, and the failure of the soil to absorb the sewage rapidly. Following this sub-surface system, a second plant was constructed in 1900. It comprised a circular reservoir or collecting tank, means for aerating the sewage, contact filters and subsidiary filters of gravel and coke. The capacity of the tank was about equal to one day's flow. The effluent was very offensive and proved to be a decided nuisance on account of the location of the plant near the main building of the Home. Furthermore, the contact filters and subsidiary filters also did not prove to be successful, partly on account of poor operation, with a result that this portion of the plant at times also created a considerable nuisance from odors. The plant was abandoned in the summer of 1903.

Following the failure of the second plant, a new one was planned and constructed in 1903. Plans for the new plant were submitted to the State Board of Health and were approved in August, 1903, provided the analyses of the sand proposed should prove to be of satisfactory quality. In October of the same year the plant was approved without any conditions. The third sewage purification plant to be installed at the Home, and at present in use, comprises a dosing tank discharged by two alternating siphons on to sand filters of artificial construction.

EXAMINATIONS AND INSPECTIONS.

During this investigation this plant was visited on three occasions. A preliminary inspection was made on April 12, 1906, followed by a detailed examination on Aug. 9, 1906, and a final inspection on Oct. 31, 1907.

DESCRIPTION OF PLANT.

The present plant is located about 600 to 800 feet from the main building of the Home on a fenced tract of land 0.25 acre in area.

Screen Chamber.

The crude sewage is first screened through ½-inch iron rods 1¼ inches center to center. This screen is 7.5 square feet in area and is inclined at an angle of about 15 degrees to the vertical. It is contained in a brick chamber 3x4 feet in plan, 2 feet deep at the inlet and 3 feet at the outlet. The screen chamber is enclosed by a wooden cover and is located adjacent to the boiler house.

Dosing Tank.

The screened sewage passes directly from the screen chamber to the dosing tank, about 600 feet distant. This tank is constructed of brick with walls 8½ inches thick and is 8x12 feet in plan and 5 feet deep and has a capacity to the flow line of about 3,240 gallons. The tank is discharged by two 12-inch alternating siphons. These discharge through about 85 feet of 8-inch pipe into two pentagonal gate chambers, each with four sides 3 feet in length and one side 3 feet 4 inches in length. The flow from the gate chamber is controlled by 8-inch lipped iron shear gates. A separate 8-inch discharge pipe for each of the alternating siphons leads from the dosing tank to the respective gate chambers. For use in case of an emergency, a by-pass is provided in the side of the dosing tank at the bottom. This pipe, which is controlled by an 8-inch gate valve, allows the direct discharge of the sewage into one of the distribution manholes. The dosing tank is entirely underground and is covered with a brick arched roof, in the top of which is a 30-inch circular manhole.

Filters.

The purification of the sewage is effected in sand filters of artificial construction. These are four in number, each is 50x50 feet in plan, with a total available area of 0.23 acre. The filters are surrounded by earth embankments and the four units are separated in like manner. (See Plate XXXIX.)

Filtering Material. The filters as originally constructed contained 4 feet 4 inches of filtering material over the depressions in which the underdrains are laid, decreasing to 3 feet 8 inches at the sides. The filtering material comprises broken stone for the lower layer and a sharp sand for the main body of the filter. This sand was obtained from the Mahoning river and was hauled to the plant, a distance of about 4.5 miles. The effective size of the sand is 0.20 m.m. and the uniformity coefficient is 1.8.

In their present condition, the filters contain from 6 to 18 inches of broken stone and gravel, surmounted by sand which ranges from 2 feet to 2 feet 3 inches in thickness. The total depth of filtering material, therefore, ranges in thickness from about 2 feet 6 inches to 3 feet 8 inches. On the three visits made at the plant, advice has been given that the filters be resanded to the original grades.

This advice has not been acted upon up to October, 1907, but it is understood that this needed improvement will be carried out in the spring of 1908.

Underdrains. The filters are underdrained by a main drain which ranges in size from 4 to 6 inches. It is laid with open joints and on a 1 per cent. grade and is located in the center of each filter. There are no lateral lines of drain tile and no lantern holes nor other means of ventilation. This underdrain is laid in depressions in the bottom of the filter about 6 inches beneath the general grade of the excavation. The underdrain and the entire bottom are covered with broken stone in quantities as above stated.

Distribution Devices. The sewage flows to the filters through the discharge pipes from the siphon chamber, already described. From the gate chambers lead 8-inch pipes to the filters proper, on which the sewage is distributed by means of a wooden carrier, which has a total length of 48 feet 6 inches. This carrier is built of ¾-inch lumber and is 6 inches deep throughout its length. The width varies from 2 feet 1 inch to 7 inches. At the change of section there is provided a slab of 1½-inch lumber. This slab, which is intended to prevent undue disturbance of the sand during dosing, is 2 feet 10 inches wide and 8 feet long. The distributor extends from one corner to the center of each unit.

Effluent Discharge. The effluent from the filters flows by gravity through about 20 feet of 6-inch pipe, which leads to the small stream adjacent to the plant. No special means are provided for protecting the filters against floods, as there is little likelihood of endangering high water, in view of the restricted watershed of the small stream into which flows the effluent from the plant.

Sewage Flow.

During this investigation, at the request of the State Board of Health, daily records have been kept of the number of discharges of the dosing tank, and from these data there has been estimated the volume of crude sewage. The dosing tank discharges on an average of five times daily; the minimum discharges are four and the maximum seven. On this basis the average sewage flow of the institution is about 15,000 gallons (100 gallons per capita), the minimum 13,000 gallons and the maximum 23,000 gallons. Practically all of the sewage reaches the plant in about fourteen hours.

COMPOSITION OF CRUDE SEWAGE.

During this investigation one examination was made at this plant, during which samples were collected of the siphon discharges for one day. The several discharges were mixed together in equal portions to form an average. From the analytical data tabulated at the close of the discussion of this plant, it appears that the crude sewage is of average strength, showing practically no especially noteworthy features.

OPERATION.

The operation of the sewage plant is in charge of the engineer of the institution under the general supervision of the superintendent. During this investigation daily records have been kept of the more important features of operation with special reference to the volume of sewage flow, operation of the filters, cleaning, plowing, etc.

Considerable coarse material reaches the sewers and is intercepted by the screen, which is cleaned several times each week. The screenings are removed and burned under the boilers. The actual quantities of the screenings cannot be accurately estimated.

Under ordinary operating conditions, sewage from the dosing tank is automatically diverted alternately to the two distributing manholes or gate chambers and the filter receiving sewage in each set of two filters is changed daily. The dosing siphons have been found to be in good condition on two of the visits to this plant, but on the inspection in October, 1907, the vent pipes had become clogged and one of the siphons was not discharging regularly. The engineer of the plant was advised to remove and clean the vent pipes.

Corresponding to the average daily sewage flow, the average rate of filtration is 65,000 gallons per acre per day; the actual rate with but one-half of the total area in use in 24 hours is, of course, twice this rate, or 130,000 gallons in 24 hours. Based upon the area of the filters, the raw screened sewage of the Home is treated at the rate of 650 persons per acre. It is the practice to rake the filters from time to time and from June, 1906, to November, 1907, according to the records kept at the plant, the filters were raked five times. Preparatory to winter, the filters are plowed and furrowed as was done in November of 1906 and 1907. The engineer of the Home devotes a few minutes of each day to the care of the sewage plant, but when the filters are plowed or scraped, additional labor is employed.

EFFICIENCY.

From the results of the analyses of samples collected during the one detailed examination of this plant and from the two inspections carried out during this investigation, it appears that the filters ordinarily purify the sewage of the institution to a very satisfactory degree. The appended analyses of the effluent collected in August, 1906, for a period of 12 hours, show a satisfactory effluent, which contains but little organic matter. Conditions found on the final inspection of the plant in October, 1907, however, indicate that at times the effluent is not well purified, since during this visit it was found that the alternating siphons had begun to show some signs of clogging, resulting in the application of too large a dose of sewage with an attendant decreased efficiency on the part of the filters. At each visit it has been observed that the sewage during the dosing of the filters causes considerable disturbance of the filtering material at the points of discharge of the wooden distributing troughs. These holes are about 12 square feet in area and 18 to 24 inches deep. This condition, no doubt, tends somewhat to deteriorate the quality of the effluent and this feature, combined with the reduced thickness of the fine grain material on the filters, suggests a much improved efficiency if the filters be resanded to the original grades, as it is proposed to have done in the spring of 1908.

In general, however, the plant affords an excellent effluent and the present plant has successfully prevented a local nuisance and prevents the direct organic pollution of the water supply of the city of Alliance.

COSTS.

The constructional cost of the plant was $6,000, including engineering and all appurtenances. The cost of operation is practically nothing, as no additional expense to the institution is chargeable to the operation and maintenance of a sewage purification plant.

TABLE NO. 83.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts per Million.														
			Oxygen. Consumed.		Nitrogen As					Chlorine.	Suspend'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats
					Organic		Free Ammonia.	Nitrites.	Nitrates.							
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.				
Crude Sewage.																
Aug. 10, 1906.....	12:35 P.- 5:25 P.	....	47	30	8.6	4.6	9.2	.00	0.0	23	73	43	88	.....	.....	16
Effluent Sand Filters.																
Aug. 10, 1906.....	6:45 A.- 6:45 P.	....	13	.....	0.6	.....	0.2	.04	12.0	.. ....	8	.....	.....	.....	0	.....

MONTGOMERY COUNTY INFIRMARY, DAYTON.

The largest of the county infirmaries in the state is in Montgomery county, a few miles west of the city of Dayton. According to the records of the institution, the summer population of the infirmary is 300 and that in the winter is 400.

Since the year 1899, a modern sanitary system has been in use, consisting of about 500 feet of 8-inch vitrified pipe sewers with lateral lines of 6-inch vitrified sewer pipe. These lead to a dosing tank, which is the vault in use before the present sewerage system was provided. The institution obtains water from a driven well and from estimates of the sewage flow, the daily consumption is about 10,000 gallons.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

A small stream flowing eventually into the Great Miami River passes through the institution's property, but is of too small flow to dispose of the sewage of from 300 to 400 people by dilution. Prior to the summer of 1899, the sewage of the institution was discharged into this small stream without treatment, but such unsatisfactory conditions were produced that the county infirmary directors, in the face of suits threatened by the riparian owners below, were compelled to provide for a more sanitary method for the disposal of the sewage of the infirmary.

As it would have been too expensive to construct a trunk sewer to the Great Miami river, the purification of the sewage was decided upon and in June, 1899, the infirmary directors presented to the State Board of Health for approval plans for the purification of the sewage of the institution. These plans were approved by the State Board of Health without conditions. Briefly stated, the plans contemplated the purification of the sewage of the infirmary on intermittent sand filters of artificial construction, with provisions for screening and for the collection of the sewage first in a dosing tank with siphon discharge.

EXAMINATIONS AND INSPECTIONS.

During this investigation, this plant has been visited on six occasions as follows: In 1906, on March 21, May 2-5, Oct. 28-29, and in 1907, on March 12, Aug. 14 and Nov. 21. Detailed examinations were made on May 2-5 and on Oct. 28-29, 1906; the remaining visits were for inspection only.

DESCRIPTION OF PLANT.

The filters are situated about 660 feet from the main buildings of the institution.

Screen.

The sewage is first screened in an iron basket, which has a superficial area of about 12 square feet and an opening between bars of 1 inch. The basket is hung vertically in a screen chamber about 3x4 feet in plan and 3 feet 6 inches deep. Arrangements are provided for removing the basket for cleaning.

Dosing Tank.

After screening, the sewage is received in a covered storage reservoir or dosing tank constructed of brick and concrete. The tank is 21 feet 10 inches long, 14 feet 10 inches wide and 5 feet 6 inches average depth, and has a capacity of about 13,000 gallons. The contents of the tank are discharged by a 6-inch siphon through about 300 feet of 8-inch pipe.

Montgomery County Infirmary, Dayton. General View of Filters.

Montgomery County Infirmary, Dayton. General View of Filters and Buildings. Also Shows Method of Applying Sewage.

Filters.

The actual purification of the sewage is carried out on 8 sand filters, each approximately 48x75 feet in area, or a total area of 0.66 acre. The filters are constructed of gravel and sand obtained from a bank several miles distant. An embankment which contains the main sewage carrier divides the plant into two divisions of four filters each. The several units are separated by low embankments.

Filtering Material. The original sand had an effective size which ranged from 0.16 to 0.40 m. m. and a uniformity coefficient of 2.3 to 15.4. The depth of the different layers of filtering material was originally as follows: Six inches of gravel, 2 to 3 feet of unscreened gravel, 6 inches of clean sand, a total thickness of from 3 to 4 feet. Recently (fall 1907) the layer of sand originally provided, but long since removed by frequent cleaning, has been restored with bank sand, which has an effective size of from 0.22 to 0.26 m.m. and a uniformity coefficient of 2.3 to 2.7.

Underdrains. The filters are underdrained by a 6-inch main drain and 4-inch lateral drains of vitrified sewer pipe. There are two lateral lines of underdrain tile in each filter located 25 feet apart and 12 feet 6 inches from the sides of the filters. They are laid in 12-inch depressions in the original excavation. Coarse gravel is placed over the underdrains in the trenches and also to a depth of 6 inches over the entire bottom of each filter. No means are provided for ventilating the underdrains.

Distribution Devices. The sewage from the dosing tank flows to the plant through the 8-inch sewer which is contained in the main dividing embankment. A manhole is provided opposite each pair of filters, in which the diversion of the sewage may be controlled by lipped iron shear gates. The distribution on the surface of the filters themselves is accomplished by split tile, which ranges in size from 4 to 12 inches, and is located across the center of each filter. At each reduction in cross section, a part of the tile is broken off to allow the escape of sewage. At such points also, concrete slabs are provided 4x7 feet in area. There are three slabs for each unit.

Effluent Discharge. The effluent from the filters flows by gravity through 100 feet of 6-inch vitrified sewer pipe to the adjacent stream. No protection against floods is provided, but no serious difficulties in this regard have been experienced since the plant was first placed in service.

SEWAGE FLOW.

During the detailed examination of May 2-5, 1906, a device was constructed which caused a record to be made of the height at which the siphon discharged, controlling the flow from the dosing tank. Records of this feature of the operation of the plant were kept by the clerk of the infirmary for three months. These records list the total number of discharges during this period, and this information, together with that obtained during the several visits to the plant, indicates that the sewage flow of the institution is such that the dosing tank is ordinarily filled twice in three days, with the exception of Mondays and Tuesdays, when on account of laundry operation, it is filled once on each day. From these data the average sewage flow of the institution is ordinarily from 7,500 to 10,000 gallons in 24 hours, or from 21 to 29 gallons per capita, based on an average population of 350. One visit was made on a day when the laundry was in operation and on that day the dosing tank filled in 9½ hours. Judging from the information from daily records kept at the plant from May to July, 1906, the daily quantity of crude sewage ranges from a minimum of 4,200 gallons to a maximum of perhaps 20,000 gallons.

COMPOSITION OF CRUDE SEWAGE.

The small per capita flow suggests a very strong sewage and such appears to be the case according to analyses collected during this investigation. In fact the crude sewage is perhaps as strong as any other in the state. The average samples of sewage collected on October 29, 1906, was found on analysis to contain in parts per million as follows: Oxygen consumed, 202; organic nitrogen, 66; nitrogen as free ammonia, 41; and suspended matter, 512. Neither nitrates nor nitrites were present. The full detailed analyses of these samples are appended to this report.

OPERATION.

During the greater part of this investigation, the operation of the filters has been in charge of an inmate, who has devoted his entire time to this work. Since the fall of 1907, however, the operation of the plant has been in charge of the laundry foreman.

It has been the general practice to flood the filters in strict rotation and one unit has been used for each discharge of the siphon. On this basis, the actual rate of filtration is 157,000 gallons per acre in 24 hours, but the average rate per acre in 24 hours is only 20,000 gallons or less, or 530 persons per acre. The plant has received special care and following the disappearance of sewage from a filter the thin coating of suspended matter has been at once removed, necessitating, of course, the removal of a small quantity of filtering material.

This frequent scraping is perhaps open to some criticism, as it is questionable whether or not it is actually essential for successful operation. It was done, however, with a view to causing the filters to present as clean an appearance as possible, but it eventually resulted in the removal of practically all of the finer surface material.

Generally once a week it has been the practice to flush out the dosing tank with water from a fire hose, a practice which, of course, causes an unusually large accumulation of suspended matter on the surfaces of the sand filters. These deposits also have been immediately removed. The cleaning of the filters has been carried out entirely by hand and the scraped material is removed in buckets. The scrapings are stated to have been removed from the site of the plant from time to time and used as top dressing. On a large plant, of course, such frequent cleaning of the filters would be impracticable.

Conditions of operation continued to be the same and continued scraping, as noted on October 29, 1906, had finally removed all of the sand from the filters. The renewal of the fine grain filtering material was then strongly advised. The resanding of the filters was, however, not begun until the summer of 1907, and when the plant was visited on Nov. 21, 1907, it was found that of the eight filters, five had been resanded to grade. The sand was obtained from a distant bank, from which one team could haul two loads a day. The officials stated that the resanding of the filters would be completed before winter if weather conditions would permit. On this visit it was found that a new operator had been appointed to take charge of the plant and it was his practice to rake the filters less frequently and to allow them to dry so that the surface mat of suspended matter could be removed without withdrawing so much filtering material as was formerly the case when the filters were scraped shortly after each dose of sewage had disappeared. The operation of the plant in November, 1907, continued practically as was previously the case aside from the matter of scraping just described.

EFFICIENCY.

On the preliminary inspection of the plant, the effluent appeared to be in excellent condition and the sewage of the institution was being handled by the plant without nuisance. The detailed examination carried out on May 2-5, 1906, showed, however, that while the effluent was fairly satisfactory, as reference to the appended analyses will indicate, yet it contained considerable organic matter and was in general not up to the standard usually attained by intermittent sand filters. The fairly high turbidity of the effluent, especially that of the effluent collected during the first part of the flow, suggested that possibly sewage was passing through the filters at too great a rate in some instances. Subsequent inspection of the filter in service indicated that this was correct, as it was found that in many places the fine grained surface material had been entirely removed by scraping and that in order to hasten the passage of sewage through the filter the attendant had replaced several of the gravel layers immediately over the underdrains with large stones raked from the various parts of the filters. As the effluent on this examination was found to be sufficiently purified to prevent a nuisance, no comment was made as to the desirability of making any changes in the construction of the plant. On the second detailed examination it was found that practically all of the fine sand had been removed from the filters and that there was produced a very foul, imperfectly purified effluent. Investigation indicated that each filter apparently contained several points through which the sewage could pass so rapidly that adequate purification could not be effected.

Such poor conditions were obtained, as the analyses indicate, that the infirmary directors were officially advised by the State Board of Health to at once take steps to restore the depth of fine sand to its original grade. Owing to weather conditions the resanding of the plant was not begun until the summer of 1907, and, as before stated, all of the filters had not been resanded when the plant was visited on November 21, 1907. The condition of the effluent on the inspection following the second detailed examination, just discussed, remained substantially the same. Under present conditions (December, 1907), as soon as all of the filters have been resanded, it is highly probable that a high-class effluent will result. Owing to the high actual rate of filtration which now prevails, it would probably be better to operate two units at one time. It is, of course, better practice to allow the coating of suspended matters to dry rather than to remove it at such frequent intervals as has prevailed at this plant.

SUMMARY.

While the efficiency of the plant has been very low during 1906 and 1907, its reconstruction brought about as a result of these special studies of the Board will no doubt greatly improve the character of the effluent so that the local sewage disposal problem will be satisfactorily solved.

COSTS.

The first cost of the sewage purification plant at this infirmary was $6,096.65, including construction and engineering.

The operating expenses during this investigation have been the salary of a caretaker at $25 per month and his board at the rate of $150 per annum. The total usual operating costs per annum are, therefore, $450, or $1.43 per capita. The cost of resanding the filters in the summer and fall of 1907 is estimated at about $800. It is estimated that about 530 cubic yards of sand were used. The haul was about four miles and two 1½-yard loads are said to have been hauled daily, at a cost of $3.50 per day plus board for one man and two horses, estimated at $1.00 per day, a total cost per cubic yard of about $1.50.

TABLE NO. 84.

Results of Chemical Analyses.

Date 1906.	Hour of Collection.	Temp. Deg. F.	Parts per Million.															Remarks.
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspend'd Matter.		Free Carbonic Acid.	Alkalinity.	Dissolved Oxygen.	Putrescibility.	Fats	
					Organic		Free Ammonia.	Nitrites.	Nitrates.									
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.						
Crude Sewage.																		
May 3-5.....	1:00 P.- 6:42 A.	67	138	82	40.0	29.0	46.0	0.04	0.0	87	453	345	66	235	0.0	....	....	
Oct. 28-29, ...	5:24 P.- 7:22 A.	....	202	63	66.0	23.0	41.0	0.00	0.0	44	512	408	72	.....	0.0	....	80	
Effluent Sand Filters.																		
May 5.....	15 min. after discharge began..	57	24	....	7.0	.....	8.0	0.60	8.5	....	83	18	....	.....	3.6	0	....	
May 5.....	2-hour av. of flow	57	21	....	7.0	.....	6.0	0.35	10.0	....	18	16	....	.....	3.1	0	....	
Oct. 29.....	7:30 A.- 4:50 P.	....	26	....	13.0	.....	5.0	0.21	14.0	40	86	43	....	.....	3.4	+	....	Str'g odor

GALLIA COUNTY INFIRMARY, GALLIPOLIS.

The infirmary of Gallia County is near Gallipolis, Ohio, about two miles north of the village, and has a population of about 40. The present building was built in 1906 and provisions were made for modern sanitary conveniences. The sewers comprise one line of 6-inch sewer pipe about 150 feet long. As no facilities are available for dilution, since the nearest watercourse is a brook of intermittent flow, the infirmary directors decided to provide for the purification of the sewage. The plant was constructed in 1906 and was built without receiving the approval of the State Board of Health. In general terms, the plant comprises one small intermittent sand filter, on which the sewage is discharged by gravity.

EXAMINATIONS AND INSPECTIONS.

This plant was inspected on Jan. 31, 1907.

DESCRIPTION OF PLANT.

The plant is located on about 0.1 acre tract of land, situated about 100 feet from the institution. The crude sewage flows by gravity directly to the filter.

Screen Chamber.

Provisions for screening the sewage were made but no screen was provided. The 6-inch main sewer terminates in a brick chamber 4 feet 8 inches square in plan and about 4 feet deep. This is constructed of one course of brick and is provided with a sloping wooden roof. The invert of the outfall sewer is flush with the bottom of the screen chamber.

Filters.

From the screen chamber the sewage flows directly to an intermittent sand filter, which has an area of 50x60 feet or 0.07 acre. The filter is built in excavation and the filtering material proper was hauled to the plant from some distance.

Filtering Material. The filter is constructed of 4 feet of medium fine sand.

Underdrains. The underdrains comprise a main drain of 6-inch vitrified pipe laid with open joints, into which lead two 3-inch lateral lines spaced 7 feet apart. Over the underdrains, which are laid in depressions in the bottom of the filter, there is placed a 3-inch layer of coarse stone and gravel.

Distribution Devices. The sewage flows on to the filter direct from the screen chamber under the continuous flow from the institution. The main carrier is of wood 12 inches wide and 6 inches deep and extends along one side of the filter. Diversion of the sewage on the surface of the sand is effected by means of hinged gates, which are placed at 12-foot 6-inch intervals along the main carrier. Shallow trenches about 3 feet apart on the surface of the filter form practically the method of distribution of the incoming sewage.

Method of Discharge. The effluent from the filter flows by gravity through a few feet of vitrified pipe which leads to a small brook. The plant is so located that there is no danger of floods.

SEWAGE FLOW.

On the basis of a per capita water consumption of perhaps 40 gallons, the sewage flow daily is about 1,600 gallons.

OPERATION AND EFFICIENCY.

Very little labor is involved in the operation of this small plant, which receives practically no attention save for perhaps an occasional change of the open gates in the main sewage carrier. From time to time it is also necessary to rake the surface of the sand so that the sewage will pass to the underdrains readily at all times. The superintendent of the institution has charge of the operation of the plant.

The single visit to this plant was an inspection and judging from the appearance of the effluent and from the general condition of the plant, the sewage of the institution was being treated without offense. The rate of filtration in gallons per acre per day is 23,000 or on the basis of 570 persons per acre and it is apparent that this figure is sufficiently low so that with proper attention to operation, the sewage of the institution should be well purified by the plant.

COSTS.

Information obtained from the infirmary directors shows the cost of the plant to have been about $400. The several items of cost are as follows:

Excavation, 425 cu. yds	$101 60
Pipe, cement, brick and lumber	38 65
Filtering material, 335 cu. yds	217 75
Engineering	37 60
Total	$395 60

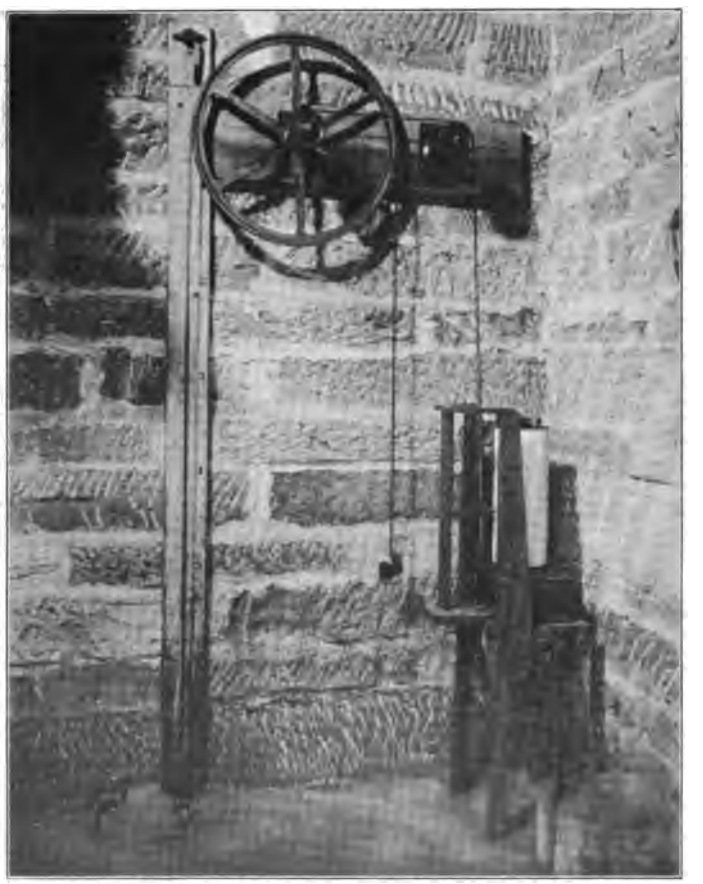
The cost of operation is practically nothing.

GALLIPOLIS STATE HOSPITAL FOR EPILEPTICS.

The state hospital for epileptics lies one mile northeasterly from the city of Gallipolis, Gallia County, on an elevated plateau near the Ohio River. The institution drains naturally into Mill Creek, an intermittent stream which enters the Ohio River about 300 feet below the sand bar, in which are located the wells from which the city of Gallipolis obtains its water supply. The institution had a population in 1907 of about 1,675, of which about 1,450 were in the main building and about 225 in Cottage I. Its water supply for drinking purposes is obtained from driven wells and for all other uses from the public supply at Gallipolis.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

Prior to 1898, very crude facilities existed for the removal of the sanitary wastes of the institution. The largest cottage of the institution, known as Cottage I, is located some distance from the main building and the discharge of crude sewage from this cottage caused such a decided nuisance that purification of the sewage from this source became obligatory. In view of this nuisance, engineering advice was sought and a report on the construction of sanitary sewers for the institution strongly advised the purification of the sewage both from Cottage I and from the main building. It further suggested that local topography would



Gallipolis State Epileptic Hospital. Device for Automatically Recording Rise and Fall of Sewage in Dosing Tank. Shows Method of Reducing Motion. Also Recording Drum Operated by Clock Work.

entail the construction of two distinct sewage purification plants. Funds were subsequently provided by legislative authority and engineers retained in 1898 submitted complete plans for sewerage and sewage purification. These plans were submitted to the State Board of Health in 1898 and were approved. As presented, the plans proposed to collect the sanitary wastes of the main buildings in a large dosing tank, which would automatically be emptied by a siphon. The flow from this tank was then led by a long inverted siphon to intermittent sand filters located somewhat less than a mile distant. A supplementary area was also provided to be used for broad irrigation. These plans provided for the disposal of the sewage from the main buildings alone. To treat the sewage of Cottage I, plans for a second plant were presented to the Board and were approved in 1898. This small plant comprises a storage reservoir or dosing tank, discharged automatically onto trenches of sand or elongated sand filters located in the valley some distance from Cottage I.

The sewage from the main buildings, collected in a system of pipe sewers which range in size from 6 to 10 inches, is conducted through a 10-inch trunk sewer to the dosing tank. The sewers for Cottage I comprise about 1,000 feet of 8-inch sewer pipe, which also leads to a dosing tank.

EXAMINATIONS AND INSPECTIONS.

During this investigation the hospital was visited on five occasions. Detailed examinations were carried out on May 8-10, 1906, and June 5-6, 1907, and inspections on March 24, 1906, January 31, 1907, and February 26 to March 2, 1907.

MAIN BUILDINGS' PLANT.

DESCRIPTION OF PLANT.

The purification of the sewage from the main buildings is carried out on a 3-acre tract of land near the Hocking Valley Railroad, about ¾ mile east of the main buildings of the institution. The filters are well removed from habitation and the site is well adapted for sewage purification. About 15 acres of farm land, which has been underdrained and lie adjacent to the artificially constructed sand filters, are used from time to time as demanded by the growing crops.

Screen.

The crude sewage is first screened through a basket screen. The basket, which has a total available area of about 12 square feet, and a clear opening between bars of 1 inch, is constructed of ⅜-inch iron bars and is suspended in a grit chamber 3x5 feet 8 inches in plan and 5 feet deep. The basket is provided with a block and tackle so that it may readily be removed for cleaning. The screen chamber is covered by an ornamental gate house.

Dosing Tank.

The sewage from the screen chamber flows into a dosing tank 15x46 feet 4 inches in plan with a depth on the center line of from 5 feet 8 inches to 7 feet 2 inches and a depth at the sides of from 5 feet to 6 feet 6 inches. The total capacity of the tank is about 15,000 gallons. The tank is constructed of brick and the walls range in thickness from 12 to 18 inches. It is covered by a brick arched roof 4 inches thick and supported by 9-inch I beams and 5-inch tie rods. Entrance may be effected by means of one 3-foot manhole located at the upper end.

The tank is discharged by a 10-inch automatic siphon through an inverted siphon of 10-inch cast iron pipe 3,600 feet long. Construction is such that the inlet and outlet of the tank are at the same end. The inverted siphon extends on a falling grade for 1,000 feet and on a continuous rising grade for 2,600 feet. The difference in elevation of the two ends of the siphon is 1.75 feet. At the low point in the siphon line adjacent to where the line crosses Mill Creek, a blow-off manhole is provided and at this point the elevation is 24.25 feet below that of the filters. To prevent air locking in the siphon, a small pipe is tapped into the 10-inch iron pipe at its high point and then lead back to the gate house.

Filters.

Sewage from the dosing tank is purified on intermittent sand filters supplemented by broad irrigation. The sand filters are eight in number, rectangular in form and each has an area of 0.25 acre. The total area of 2 acres is divided into eight units by earth embankments.

Filtering Material. The filtering material is a bank sand which was obtained a short distance from the main buildings of the institution and was delivered at the site of the plant in dump cars operated on a temporary spur track. The material is of medium size and has an effective size which ranges from 0.29 to 0.32 m.m. and a uniformity coefficient which ranges from 3.8 to 4.0. The depth of the sand is 4 feet. (See Plate XL.)

Underdrains. Each filter is underdrained by two lines of 4-inch tile spaced 50 feet apart and leading to a main 8-inch drain laid on a grade of 1 to 400. In constructing the filters, the natural surface of the ground was excavated to the proper elevation and the bottom of the filters was shaped into shallow depressions 6 inches deep and 50 feet apart. In these were laid the underdraining tile. Over this tile is a layer of coarse gravel from 2 to 6 inches in thickness. A similar layer covers the entire bottom of each filter.

Distribution Devices. The discharge from the long inverted siphon is carried to the different filters in a 10-inch pipe in an embankment which separates the several units. Small gate chambers with shear gates permit the diversion of the sewage as desired. The distribution on the individual filters is effected by a wooden carrier of changing cross sections, which starts with a section 2 feet 7 inches x 6 inches deep and diminishes to a section 12 inches by 6 inches deep at the extreme end. At the three changes of section, there are provided concrete slabs which are intended to prevent the undue disturbance of the surface sand. There is one wooden distributer in each filter and it extends from the center completely across the tank.

Effluent Discharge. The effluent flows by gravity through about 400 feet of 8-inch vitrified sewer pipe which leads to a small brook, thence to Mill Creek and eventually to the Ohio River. The nearest house is about 1,000 feet distant. To provide a protection against floods, an embankment is constructed entirely around the plant. It is presumably of a height sufficient to protect the filters from inundation except in the case of unusual floods.

SEWAGE FLOW.

The daily flow of crude sewage may be approximated by a record of the number of times the dosing tank is discharged. The discharges usually last for three or four hours, and during this period, of course, considerable crude sewage enters the tank. With a view to learning more closely the volume of sewage, in February, 1907, there was constructed an automatic recording device with a float so arranged that the rise and fall of sewage in the dosing tank, corresponding to about 7½ feet, would be reduced to about 14 inches and could be recorded on a

cylinder revolved by clockwork. This device, which is pictured on the preceding page, was in operation for a part of the year 1907. By this means there have been obtained for a considerable period an approximately correct record of the filling and discharging of the dosing tank, and in connection with the known capacity of the tank per foot it has been possible to estimate the average daily flow of sewage. Certain of the records from March 10th to June 16th, 1907, are listed below as averages for different days in the week. The average flow for the above period was 177,000, the maximum 248,000 and the minimum 114,000 gallons in 24 hours.

The per capita sewage flow in 24 hours has averaged 122 gallons. This high figure is to be explained by the use of automatically flushed closets and extensive laundry operation.

TABLE NO. 85.

Sewage Flow for Different Days of the Week.

	Gallons in 24 Hours.						
	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
Maximum	247,000	207,000	209,000	209,000	211,000	248,000	216,000
Minimum	150,000	125,000	143,000	114,000	116,000	142,000	123,000
Average	192,000	170,000	167,800	173,700	170,800	188,000	184,000

COMPOSITION OF CRUDE SEWAGE.

The general character of the crude sewage of the institution was learned from two detailed examinations. The leading features are the comparatively high temperature, generally about 65 degrees F., and the presence of suspended matters of large size and considerable fatty matters. The sewage ordinarily contains no nitrates. On the first examination, dissolved oxygen was absent, but on the second was present to the extent of 5.1 parts per million. The sewage has a peculiar soapy smell and generally shows evidences of soapy water from the laundry and kitchen. On the first detailed examination the suspended matters were only 94 parts per million, but on the second they were 258 parts per million. These samples of the crude sewage were collected at the discharge of the inverted siphon.

OPERATION.

The institution employs one man whose duty is the operation of the sewage purification plant. Sewage from the inverted siphon flows by gravity through the distributing pipe directly onto the filters, or is diverted to the irrigation area at the will of the operator.

Screening.

The operator of the sewage plant is in charge of the cleaning of the basket screen in the gate house on the main grounds of the institution. This screen is cleaned three times each week and at each cleaning about one wheelbarrow load of rags, clothing and coarse material is removed. The basket screen is so coarse that this device serves to remove merely the coarser material carried by the sewage. Thorough screening is by no means obtained, as is evident by the appearance of large quantities of suspended matter on the filters. The screen in use since the plant was first operated was out of repair during the spring of 1907,

and was subsequently replaced by a screen basket of similar construction. The screening of the sewage is especially important at this institution as large quantities of rags, clothing, etc., are thrown into the sewers by the patients.

Dosing Tank and Inverted Siphon.

Ordinarily, the operation of the dosing tank and inverted siphon requires very little attention. Occasionally, the dosing tank becomes clogged with suspended matter. This clogging is generally about the bell of the siphon and tends to prevent the restoration of atmospheric pressure within the bell at the end of a discharge, and hence causes dribbling and a very protracted discharge. The inverted siphon has been in successful operation since it was constructed. The valve was opened at the low point or blow-off in the spring of 1907, and a considerable quantity of suspended matters was removed. Ordinarily, there has been no very marked tendency to clog.

Sand Filters and Irrigation Area.

The sand filters are operated at such times as the sewage may be applied to them without interfering with the crop of corn which is annually raised on the filters. The corn is planted in hills about 30 inches apart and in the center of furrows which are about 3 feet on centers. Ordinarily, one entire siphon discharge is allowed to flow onto one unit, but in case conditions are such that an entire discharge would overflow the corn hills, the flow of sewage is then diverted to a second unit. It is to be noted that the purification of the sewage on the filters during the summer months is of secondary importance to the raising of a successful crop of corn. The experiment of raising a second crop in one season did not prove a success. When the sand filters are not used, the sewage is diverted to the irrigation area of 15 acres. The filters are generally furrowed and in this connection pass the winter without difficulty. About twice a year, according to the caretaker, certain portions of the clogged material are removed. It was stated that each of the eight units yields about 40 wheelbarrow loads of clogged sand which corresponds to 320 loads for the plant, or 160 loads or 11.4 cubic yards per acre at each cleaning. During the spring visit to the plant it was noted that considerable suspended matter was reaching the surface of the filters on account of a broken screen basket, a condition which entailed considerable labor in keeping the filters clean.

The location of the plant is such that it is not effected by high water, although the flood in the Ohio River in the spring of 1907 caused the water to rise within two feet of the top of the protecting embankment. On account of the use of the farm land for irrigation purposes, it is impossible to state the actual rate of filtration per acre. Corresponding to the usual practice, however, the actual rate of filtration is 356,000 gallons per acre in 24 hours and the net rate for the entire area of artificial filters is 89,000 gallons per acre in 24 hours. This corresponds to 725 persons per acre receiving sewage which has received only rough screening as a preparatory treatment. It is probable that the farm land has received a large share of the sewage of the institution.

EFFICIENCY.

The sewage of the institution has been purified by this plant without offense, and in general the plant may be said to have been well operated and to have been productive of excellent results. Two sets of average analyses are available from this investigation, and in each case the analyses indicate that the sewage is purified to a very high degree. Ordinarily, the effluent from the sand filters is clear and odorless, and contains a large quantity of nitrified nitrogen. The plant is excep-

tionally well handled and the good results which have been obtained in view of the disposal without offense of the sewage of 1,425 persons illustrates the advantage of careful and intelligent and continuous supervision in the operation of intermittent sand filters.

COSTS.

The total cost of a part of the sewer system and the sewage purification plant was $13,600 and of this amount $4,893 was paid for land, the gate house and main sewer, so that the net cost of the sewage purification plant proper was $8,707. The individual items in the construction of a part of the sewerage system and sewage purification plant are as follows:

Land	$1,126
Gate house	1,590
Main sewer	2,177
Sand filters	8,707
Total	$13,600

The yearly operating expenses have been very low and are ordinarily the wages of the caretaker, at $35 per month or $420 a year. There were practically no outside expenses during the year 1906, but in 1907, the screen basket was renewed at a cost of about $40. The ordinary operating expense of the plant is the salary of the caretaker at $420 per annum and is at the rate of 29 cents per capita.

COTTAGE I PLANT.

DESCRIPTION OF PLANT.

The sewage plant for purifying sewage from Cottage I is located about 1,000 feet distant from the cottage and receives the sewage from about 225 persons. The plant is of somewhat novel construction, as the purification proper is effected on elongated filters or sanded trenches.

Screen.

The crude sewage from Cottage I first receives screening in a basket screen suspended in the inlet end of the dosing tank. The basket screen is similar to that already described for the main buildings. Arrangements are also available for removing the basket by means of a block and tackle.

Storage Reservoir of Dosing Tank.

After screening, the sewage is received in a storage reservoir or dosing tank, 9 feet 11 inches by 21 feet 10 inches in plan with a depth to the flow line on the west elevation in the corners of 5 feet 8 inches and on the center 6 feet; at the east elevation the corners have a depth of 5 feet and on the center line a depth of 7 feet. The capacity to the flow line is about 9,500 gallons. The tank is constructed of brick and is discharged by a single 6-inch siphon through a short length of 8-inch pipe. To provide for periodic removal of deposits from the bottom of the tank, there was arranged a grid of 2-inch pipes pierced with ¼-inch holes 6 inches on centers with the axes of the holes directed towards the bottom of the tank. A connection controlled by a valve was arranged to allow the discharge of water through this grid. This device has not been in operation for several years.

FILTERS.

The sewage from the dosing tank is received on sand trenches eight in number, 4 feet wide and from 300 to 400 feet in length, with a total area of about 11,200 square feet, or 0.26 acre. Between the trenches are strips of natural soil, 6 feet wide.

Filtering Material. The trenches are filled with 3 feet of sand which is graded on the surface to a slope of about 2 inches per 100 feet. The filtering material has an effective size of from 0.27 to 0.28 m.m. and a uniformity coefficient of from 3.0 to 3.2.

Underdrains. The trenches are underdrained at 20-foot intervals with lines of 4-inch tile pipe, which are laid at right angles to the length of the trenches and are connected with a main drain of 6-inch tile. No coarse material is placed over the tile.

Distribution Devices. Sewage from the dosing tank flows into a wooden trough which contains wooden shear gates opposite each line of trenches and thus permits the diversion of the sewage to one or more trenches at will. The upper 8 feet of each trench is provided with a concrete slab which is intended to prevent undue washing of the upper part of the trench when the dose of sewage is being applied. Further to facilitate the distribution of sewage in the trench, the latter is sloped from the inlet to outlet as already mentioned.

Effluent Discharge. The purified sewage flows by gravity from the trench filters through about 800 feet of 6-inch pipe. While there is practically no danger from high water, yet local topography is such that during heavy rains the trenches would receive considerable clay wash, and consequently to avoid this feature a ditch is constructed on the side of the plant adjacent to the hill.

SEWAGE FLOW.

Information as to the sewage flow at this plant is obtainable from a record of the number of daily discharges of the dosing tank. On the first detailed examination, the tank discharged five times in 24 hours, corresponding to a daily flow of 47,500 gallons or at the rate of 211 gallons per person tributary. On the second detailed examination, the tank discharged three times, corresponding to a per capita flow of 127 gallons. The large consumption of water at Cottage I is explained by the use of automatically operated closets, by extensive bathing and the laundry operation.

COMPOSITION OF CRUDE SEWAGE.

Available information from analyses of the average samples collected respectively on the two detailed examinations of the plant, shows that the sewage is exceedingly dilute. The greater proportionate use of water at Cottage I, as against that of the main building, is clearly shown by the character of the crude sewage which in the case of Cottage I is very fresh and contains nitrates and dissolved oxygen at all times. The suspended matters are a feature of the sewage and at times large rags and articles of clothing are caught on the screen in the dosing tank. The sewage is also noteworthy on account of its comparatively high temperature.

OPERATION.

The operation of Cottage I sewage purification plant is in charge of the engine man at the cottage. The plant, however, is practically automatic in its operation and the attention required is merely the cleaning of the screen and the changing of the gates flooding the several trenches.

Screening.

The basket screen intercepts a large quantity of coarse material and should be cleaned at regular intervals. During this investigation the plant has been practically neglected, as found on each visit the screen was badly choked up and the dosing tank was badly clogged.

Dosing Tank.

The dosing tank itself has received but little supervision and the choked screen has resulted in serious clogging so that the operation of the siphon has been greatly hampered. On the first detailed examination of the plant, a full dosing tank was discharged in about 30 minutes. On the examination in June, 1907, however, the period of discharge was increased to 12 hours. In view of the fact that the siphon was clogged, it could not be properly vented, and continued to discharge for a long period with a very small flow of sewage.

Trench Filters.

The poor supervision which the plant has received is clearly illustrated by the condition of the trenches which have been allowed to become clogged with sewagic material because the diverting gates have not been changed at sufficiently frequent intervals. Early in this investigation it was pointed out to the officials of the institution, that the trenches would be ruined by a deposit of clay carried down by rains from the adjacent hillside, subsequently a ditch was dug to prevent the deposit of clay on the trenches, and the filters in the summer of 1906 were cleaned and placed in order. The plant continued to receive very poor supervision and the ditches again became coated with suspended matters and were very foul. On the detailed examination of 1907, they were again cleaned and were refilled to grade with coarse sand. Ordinarily, four trenches are in service, although there has been no regularity in the application of sewage. The average rate of filtration is 110,000 gallons in 24 hours, or 865 persons tributary per acre. After four years of service, the wooden distributors have entirely rotted out, and should now be replaced by distributors of concrete construction. The labor of cleaning the trenches is done by the patients; no special records have been kept of the number of men and of the number of hours of employment.

EFFICIENCY.

Notwithstanding poor supervision, the weak sewage of Cottage I has been fairly well purified and without nuisance from odors. Analytical evidence obtained during this investigation indicates that the effluent from this plant is by no means so highly purified as that from the main buildings plant. This feature is probably explained by the fact that the latter plant receives greater care and that there is an absence of clogging which has been in evidence in the trench filters at practically all visits.

To improve the general condition of the Cottage I plant, it is advised that a special caretaker be appointed who shall visit the plant daily, for the purpose of changing the gates, removing obstructions from the screen and clogging matters from the surface of the trenches. It is also highly desirable that the wooden distributing troughs be replaced with concrete construction.

COSTS.

The construction cost of the system was about $700. This cost is exclusive of labor which was performed by the patients of the institution. The operation of the plant practically adds nothing to the cost of maintenance of Cottage I.

TABLE NO. 86.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts per Million.															
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspend'd Matter.		Free Carbonic Acid.	Alkalinity.	Dissolved Oxygen.	Putrescibility.	Fats.
					Organic		Free Ammonia.	Nitrites.	Nitrates.								
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.					
Main Buildings.			*Crude Sewage (Average Discharge Dosing Tank.)*														
May 7-8, 1906....	7:56 P.-11:45 A.	60	58	31	10.8	5.2	18.0	0.42	0.0	80	137	.....	22	270	0.0	....	....
May 8, 1906.....	11:45 A.- 8:20 P.	66	61	27	9.1	5.4	7.5	0.00	0.0	78	44	35	13	.....	.....	....	....
May 8-9, 1906....	8:20 P.-11:50 A.	67	50	30	11.8	8.5	11.2	0.50	0.0	80	64	.....	16	.....	.....	....	....
May 9, 1906.....	11:50 A.- 7:50 P.	61	61	36	10.1	5.4	13.8	0.01	0.0	81	130	100	22	.....	.....	....	....
Feb. 1, 1907.....	12.00 M.- 3.00 P.	....	56	40	4.7	3.2	10.4	0.14	0.0	77	97	75	.....	.....	.....	....	84
June 5-6, 1907....	10:24 A.- 8:00 A.	67	24	15	3.0	1.0	13.0	0.20	0.0	85	258	93	33	.....	5.1	....	45
			Effluent Sand Filters.														
May 8, 1906.....	8:42 A.- 4:42 P.	63	21	....	1.37	.....	0.16	0.00	10.0	82	5	.....	.....	.....	7.3	0	....
May 8-9, 1906....	6:00 P.- 2:00 A.	62	13	....	0.51	.....	0.28	0.00	11.0	82	18	....	.....	.....	6.8	0	....
May 9, 1906.....	6:00 A.- 2:00 P.	62	9.0	....	0.53	.....	0.28	0.06	27.5	....	12	.....	.....	.....	.....	0	....
May 9, 1906.....	2:30 P.- 9:00 P.	61	7.8	....	0.84	.....	0.12	0.00	10.0	....	5	.....	.....	.....	.....	0	....
May 9-10, 1906...	9:30 P.- 5:00 A.	60	7.9	....	0.33	.....	0.12	0.00	10.0	....	5	.....	.....	.....	.....	0	....
Feb. 1, 1907.....	11:00 A.- 5:00 P.	....	19.9	....	5.60	.....	1.40	0.15	10.0	90	23	17	.....	.....	.....	0	....
	12:30 P.-10:00 P.																
June 5-6, 1907....	4:00 A.- 9:00 A.	62	3.9	....	0.80	.....	0.10	0.01	17.5	....	46	26	.....	.....	6.4	0	....

40 s. E. of H.

Cottage I.																		
							Crude Sewage.											
May 7-8, 1906....	8:53 A.- 5:30 P.	60	34	23	6.8	5.7	8.0	0.30	0.5	79	31	.....	10	.....	0.0	....	....
May 8-9, 1906....	5:33 P.- 5:30 A.	60	16	14	6.1	4.0	4.0	0.12	0.4	78	32	16	7	.....	8.5	....	....
Feb. 1, 1907.....	10.40 A.-11:25 A.	....	58.4	40.6	9.4	7.4	2.6	0.15	2.0	180	145	129	.....	.....	.....	....	116
June 6-7, 1907....	11:40 A.- 6:25 A.	65	22	14	9.0	5.0	3.0	0.26	2.0	83	93	64	7	.....	5.3	....	65
							Effluent Trench Filters.											
May 8, 1906.....	9:30 A.- 8:00 P.	54	13	....	1.4	.....	1.20	0.20	4.8	....	12	.....	.....	.....	4.3	0	....
May 8-9, ...	8:00 P.- 6:31 A.	54	8.9	....	1.3	.....	1.08	0.17	0.4	93	5	.....	.....	.....	.....	0	....
Feb. 1, 1907.....	11:30 A.- 6:00 P.	....	26.5	....	6.2	.....	1.80	0.13	3.0	120	22	17	.....	.....	.....	0	....
June 5-6, 1907.....	1:00 P.- 6:30 A.	64	3.9	....	1.1	.....	2.90	0.20	6.0	....	48	30	.....	.....	4.8	0	....

DENISON UNIVERSITY AND SHEPARDSON'S COLLEGE.

Denison University and Shepardson's College are in Granville in Licking County, and are on land which drains into Raccoon Creek, a tributary of the Licking River. The combined population in the college year is about 500 to 600, but during vacation in July and August, it is only about 25.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In the year 1897, the trustees of Shepardson's College made application to the State Board of Health for an approval of plans for the purification of the sewage of the college. The Secretary of the Board made an investigation and reported that the system proposed was broad irrigation, to be carried out on land located about 1800 feet from the college buildings. In April, 1897, the Board approved the plans for a system of sanitary sewers and for sewage purification, but suggested that the greatest care be taken in constructing the filters so as to prevent ponding and imperfect filtration. It was suggested also that as large an area as possible be utilized in order to allow long resting periods. Shortly after construction, the sanitary sewers of Denison University were connected to the plant, so that it actually affords a means for the purification of the sewage of both colleges.

INSPECTIONS.

This plant was visited by the assistant engineer on April 5, 1906. No detailed examinations were carried out during this special investigation.

DESCRIPTION OF PLANT.

The sanitary sewage of Denison University is collected in an 8-inch sewer which joins the older 6-inch sewer in which is carried the sewage from Shepardson's College. The 6-inch sewer is about 2200 feet in length and has a steeper gradient than the 8-inch sewer and is of sufficient capacity to carry the flow from both institutions. The sewers of Denison University collect sewage from two college dormitories, with a population of about 100, and those of Shepardson's College allow the removal of the sewage from a dormitory with 122 students, that from several dwellings and also the sink drainage from a few adjacent residences. There are two large swimming pools connected with the sewers. Water is generally removed from these pools several times each week.

The irrigation field is about one acre in area and was prepared by stripping the surface soil and by laying 2 feet below the surface, 10 lines of 4-inch tile, about 20 feet apart. These 4-inch tiles drain into a 6-inch drain which leads to Raccoon Creek, a distance of about 600 feet. The surface of the field is formed into ridges and depressions which are located mid-way between the underdrains so that the ridges are directly over the drains. With a view to causing a greater lateral movement of the sewage the bottom of the depressions is made practically flat. The furrows are nearly level throughout their length and except, of course, at times of heavy storms are not pitched sufficiently to cause the sewage to flow more than one-third or one-half of the distance to the extreme end. The filtering material comprises about 3 feet of sandy loam which overlies a bed of gravel. The plant is only about 500 feet from the nearest house, and besides there are a number of houses within 1,000 feet.

Boys' Industrial School, Lancaster. General View of Filters.

Boys' Industrial School, Lancaster. — Stream Which Receives Effluent.

OPERATION AND EFFICIENCY.

No information is available as to the volume of dry weather sewage flow. At times of storms it is understood that the sewage flow is very great and that the sewage is generally very weak, as was noted on the above inspection.

Very little attention is necessary in the operation of the plant and one man for two hours a week is sufficient to operate the plant successfully. At the inspection it was stated that the efficiency of the plant has been such that even though located a short distance from inhabited buildings, no nuisance is said to occur at any season of the year. Possibly the absence of odor is explainable by the fact that the plant receives no sewage during the two warmest months of the year when odors from a ponded sewage field would be most pronounced. Inspection shows that very little care is necessary in operating the plant. The actual labor involved consists in the summer time in removing weeds and cutting grass. Several times each week the attendant changes the flow of sewage. By this means there is afforded a certain intermittency in the operation of the different parts of the area. Sewage tends to pond in the trenches during the dry weather and the furrows are partly filled with sewage at all times. Except during stormy weather, the porous nature of the soil at the plant prevents the appearance of the effluent in the main underdrain, since the purified sewage flows through the open joints of the main underdrain and disappears in the porous soil. On this account it is not possible to judge the efficiency of the plant from the standpoint of the effluent, but it seems probable that a fair purification is effected especially since the sewage passes through a considerable thickness of excellent filtering material before reaching the ground water level or Raccoon Creek.

COSTS.

The first cost of the plant was about $800 a figure which includes land, grading and the construction of underdrains. The cost of operation is very slight and comprises practically the labor of one man two hours per week.

LANCASTER BOY'S INDUSTRIAL SCHOOL.

The Boys' Industrial School is a state institution situated on high ground in Fairfield County about six miles west of the city of Lancaster. According to the official records of the institution, the total population during the year 1907 was about 1,150. Since 1900, the school has had an ample water supply of excellent quality, a system of sanitary sewers and a sewage purification plant. The present water supply, installed in the year 1899, is obtained from driven wells. The daily consumption is stated to be from 100,000 to 125,000 gallons.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In 1898 there was a serious epidemic of typhoid fever at the institution. The State Board of Health made an investigation and found that the epidemic was undoubtedly due to impure water, caused in part by improper sewage disposal facilities. The outbreak of typhoid fever at the school necessitated urgent measures for obtaining an improved water supply. Accordingly, application was

made to the emergency board of the legislature for funds for a new supply. Engineering advice was sought and the sanitary engineer retained suggested a system of driven wells, as now in use and advised further the construction of a new system of sanitary sewers and the purification of the resulting sewage. Funds for a new water supply, a new sewer system and for the construction of the sewage purification plant was subsequently obtained from the state legislature.

The natural drainage of the institution, which is on a plateau about 150 feet above the general level of the valley, is a small brook which eventually flows into the Hocking River. The disposal of the sanitary sewage of the institution by dilution was entirely impracticable on account of the intermittent flow of the stream, and it was, therefore, deemed necessary to provide for sewage purification.

The sewerage system then constructed comprises vitrified pipe sewers which range in size from 6 to 10 inches. The lateral sewers comprise about 5,000 feet of 6 and 8-inch pipe, which lead to a trunk sewer of 9 and 10-inch pipe about 4,000 feet in length. The system is provided with three flush tanks and manholes at each change of grade. There is a drop of about 150 feet from the main buildings of the institution to the point to which the sewage is conducted for purification.

Plans for the sewerage of the institution and for the purification of the sewage were approved by the State Board of Health in May, 1899. The purification plant in general terms embodies the treatment of the screened crude sewage on sand filters of artificial construction to which the crude sewage flows by gravity.

EXAMINATIONS AND INSPECTIONS.

Visits to the school were made in 1906 on March 23, May 18, October 16, and Nov. 1 and in 1907 on May 2-3. With the exception of the first and fourth visits, detailed examinations were made on these dates. Several other visits were made in connection with the co-operative study of the disinfection of sewage effluents.

DESCRIPTION OF PLANT.

The purification of the sewage of the school is carried out on 23 sand filters which have a combined area of about two acres. (See Plates XLI. and XLII.)

Screens.

The crude sewage is first screened through ½x1¼-inch iron strips spaced ¾-inch apart. The screen has an area of 24 square feet and is inclined to the vertical about 70 degrees. The screening of the sewage is carried out in a covered brick chamber, 4x8 feet in plan, 5 feet 5 inches deep at the inlet side and 3 feet deep at the outlet. The 10-inch main sewer enters 12 inches from the bottom and discharges flush.

Filters.

An electric railway passes through the valley and this fact, together with the natural topography necessitates small units, and causes the plant to have a somewhat elongated appearance.

The individual filters range in size from 0.062 to 0.097 acre. Representative dimensions are 60x44.5 and 90x44.2 feet. The total area is about 2 acres.

Filtering Material. The filters are constructed of sand obtained by crushing sandstone from a quarry near the plant. The sand has an effective size of about 0.21 m. m. and a uniformity coefficient of 2.0. The filters are from 3.5 to 4.0 feet in depth. They are separated from each other by earth embankments.

Underdrains. The system of 23 filters is underdrained by a main drain of 24-inch vitrified pipe located from 2 to 6 feet from the railroad. Each filter contains lateral drains of 4-inch pipe laid about 6 feet apart in trenches formed by depressions in the natural grade of the bottom. These laterals are connected to the main collecting drain by means of Y's and ⅛ bends. No coarse material is placed over the underdrains and no special means are provided for ventilation.

Distribution Devices. The sewage from the institution carried by the 10-inch main sewer along the slope of the valley flows directly to the purification plant without arrangements for dosing. To divert the sewage to a given set of filters, there are 13 brick gate chambers. There are three single chambers which contain one shear gate each and ten double chambers which supply two filters each. Twelve-inch pipes lead from the gate chambers to the filters. On one side of each filter, to distribute the sewage, there is a line of 12-inch split tile, alternate unions of bells and spigots are not entirely cemented and thus is permitted the escape of sewage onto the filter.

Effluent Discharge. The 24-inch main drain terminates at a concrete culvert whence the effluent flows into the small brook which leads to the Hocking River. At the last gate chamber it is possible to divert the entire flow of sewage untreated. No protection against floods is provided for, and during the heavy rains of spring, the plant is at times inundated since the 24-inch effluent drain serves as well to carry the run-off from some of the adjacent slopes. The plant is well isolated and the nearest building of the institution is about one-half mile distant and at an elevation of 150 feet above the plane of the filters.

SEWAGE FLOW.

On each detailed examination, the flow of crude sewage was weired. The first series of measurements which continued for 24 hours, indicated an average sewage flow of 63.000 gallons, or 55 gallons per capita. It was noted that the rate of the night flow from the hours of 12:30 o'clock a. m. to 5:00 o'clock a. m. was 25,000 gallons, a fact which suggested that there was a considerable waste of water due to leaky fixtures. The next examination on October 16, 1906, continued for about 12 hours when measurements were arrested in view of a heavy storm, which caused a large increase in the flow of sewage. The rate of flow in gallons per 24 hours increased to 329,000 gallons, and it was found that this large increase during wet weather was due to the fact that the roofs of practically all of the institution's buildings are connected to the sanitary sewers for flushing purposes. Further information as to the sewage flow were learned on the third detailed examination, when the average flow was found to be 58,000 gallons in 24 hours or 50 gallons per capita. The night flow or leakage was then high as the data tabulated below indicate. In connection with the sewage flow at this institution, it is to be remarked that a swimming pool holding 55,000 gallons is discharged once a week into the sanitary sewers. Data illustrating the hourly variation of sewage flow are presented in the next table.

The sewage flow and the flow of effluent at the plant are somewhat different as the effluent drain serves also to carry off water from the neighboring hills.

TABLE NO. 88.

Flow of Sewage at Different Hours of the Day on May 2-3, 1907.

Hour.	Rate of Flow. Gals. in 24 Hours.	Percentage of Average.	Hour.	Rate of Flow. Gals. in 24 Hours.	Percentage of Average.
6:00 A. M.....	126,000	217	6:00 P. M.....	43,000	74
7:00 "	61,000	105	7:00 "	50,000	86
8:00 "	91,000	157	8:00 "	43,000	74
9:00 "	80,000	138	9:00 "	61,000	105
10:00 "	138,000	248	10:00 "	43,000	74
11:00 "	70,000	120	11:00 "	43,000	74
12:00 "	61,000	105	12:00 "	43,000	74
1:00 P. M.....	50,000	86	1:00 A. M.....	43,000	74
2:00 "	50,000	86	2:00 "	43,000	74
3:00 "	43,000	74	3:00 "	43,000	74
4:00 "	61,000	105	4:00 "	43,000	74
5:00 "	70,000	120	5:00 "	43,000	74

COMPOSITION OF CRUDE SEWAGE.

The analyses of the crude sewage collected on the three detailed examinations indicate that the crude sewage is exceedingly high in organic and suspended matter. The sewage, however, generally contains dissolved oxygen, presumably introduced by the aeration afforded in the passage of the sewage from the institution to the plant. It ordinarily carries considerable paper and rags which are intercepted by the screens, although considerable finely divided fibrous matter is generally visible in the screened sewage. Representative of the aeration of the crude sewage, on the detailed examination of May 2, 1907, for a period of 24 hours, with the exception of the samples collected at 8:00 o'clock a. m. the crude sewage contained dissolved oxygen which ranged from 0.0 to 9.1 parts per million.

OPERATION.

The general supervision of the sewage purification plant at the institution is in charge of the assistant superintendent. The actual operation is carried out by a foreman and a number of boys. Their duty comprises the care of the screens, the cleaning of the filters and the change of the gates which control the flow of sewage to the several units.

Screens.

The screens at this plant intercept large quantities of rags and paper. It is stated that they are cleaned at semi-monthly intervals, and on such occasions the screenings are removed, piled in heaps, allowed to dry and are eventually buried.

Sand Filters.

The general tendency in the operation of the sand filters during this investigation has been towards more regular flooding and the use of the filters

more nearly on an intermittent basis. The method of operating the plant in vogue at the beginning of this investigation, was to allow sewage to flow onto the larger filters for 24 hours and onto the smaller filters, two of which are controlled by one gate chamber, for a period of 48 hours. It was, and is now the practice to clean the filters as soon as they are dry. After the removal of the surface mat of suspended matter, the sand is loosened by a large rake, known as a "go-devil." This is followed by a smaller rake which leaves the upper layers of the filters in a very porous condition. It is the practice to keep the filters clean and free from suspended matter at all times. Based upon the average day rate of sewage flow this method of operating the plant necessitated an actual rate of operation in the case of the smaller units of perhaps 600,000 gallons per acre in 24 hours and for the larger units of 280,000 gallons per acre in 24 hours. The net rate per acre based on the average flow of 63,000 gallons is, of course, considerably lower than this figure, or 32,000 gallons per acre in 24 hours. It was noted on the first examination that at times the filters were greatly overdosed and there was considerable evidence that at times the filters would be operated for periods of 24 hours or longer, and in fact on the first examination one of the filters in operation a few days previous was so badly clogged that it had not entirely uncovered in 24 hours.

On the next examination on May 18, 1906, conditions of operation were found to be practically the same.

In the fall of 1906, considerable attention was paid to the matter of a thorough cleaning of the filters before winter. Filter No. 13 was resurfaced with about one inch of clean sand. Filters Nos. 1 to 12 inclusive, 14, 21 to 23 inclusive, received the customary cleaning only. Filters Nos. 15 to 19 inclusive, were plowed 4 inches deep and were then thoroughly raked and carefully leveled. Filter No. 20 was spaded 4 inches deep. As a result of this cleaning, the filters presented a very creditable appearance, but there appeared to be a tendency on the part of the surface material to be out of level. With a view to improving conditions, suggestions were made to use more of the filters at one time.

Subsequent visits gave further evidence as to the operation of the plant, which was modified to correspond with the above suggestions beginning in the fall of 1906. It was found that the plant could be operated without difficulty during the winter months even though the filters were flat surfaced. The sewage of the institution has a fairly high temperature (67 deg. F.), and generally finds its way without difficulty underneath any coating of ice or snow which may form on the filters.

On the third detailed examination, the operation of the plant was found to be decidedly improved. Daily, except Sunday, the caretaker together with from four to seven boys, are engaged in removing the suspended matter from the filters. The practice continues of operating from three to four filters daily and of changing the gates in the morning and in the afternoon respectively. The method of cleaning the filters wherein practically only the dry mat of suspended matter is removed, has resulted in but a slight reduction of the initial thickness of sand. After seven years of service, the depth of sand in the filters ranges from 3.5 to 4.0 feet. In general, the sand is very clean, and a stain of organic matter is visible perhaps only in the top 3 inches of the material. Undoubtedly, the heavy coating of suspended matter serves materially to protect the sand from the penetration of the finer clogging matters. Practically all of the filters have been in successful operation, even though they were at times clogged on the surface, with the exception of filter No. 14, which as first noted in the fall of 1906 would not allow sewage to disappear freely from its surface. It was, therefore, suggested that the underdrains be examined. It was found that sand had worked its way between the bells and spigots of the underdrain

tile practically sealing the underdrains, and that there was also a low point in the grade of the drains so that the effluent could not flow freely to the main collecting drain. When the filtering material was replaced, the joints in the lateral drains were protected with coarse stones before they were covered with sand. Since that time no difficulty has been experienced in operating this filter and as is the case with the majority of the filters at the plant, sewage remains on the surface of perhaps 1 to 2 hours after the dose has ceased to be applied.

The normal operation of the plant is somewhat interrupted during rains, and during the spring of 1907 a very heavy rainfall caused the plant to be seriously flooded and placed the filters out of service for several days.

The present method of operating the plant, wherein from 3 to 4 filters are daily in service, corresponds to an actual rate of filtration of about 250,000 gallons. The total area at the plant corresponds to 575 persons tributary per acre. The above general points relative to the operation of the plant are all that are available, as no daily records were kept.

EFFICIENCY.

Former investigations of the efficiency of the plant have always shown that the sewage of the institution has been exceptionally well purified. The resulting effluent has been clear and odorless and well nitrified. Previous reports have commented on the low efficiency of the distribution and the desirability of maintaining the filters as level as possible. They have further suggested that better distribution would result were the sewage applied in larger doses. The first detailed examination of the plant during this investigation indicated that while the operation was probably sufficient thoroughly to correspond to local requirements, yet it was strongly evident that the methods of operation could be improved, and that the use of a larger area of filters each day would probably effect a greater purification of the sewage. It was brought out that the rates of filtration were higher than could probably be successfully maintained with best results from intermittent sand filters. Indications were at hand that the distribution was poor and that considerable surface clogging was in evidence. The purification of the sewage was being effected without nuisance, but a decided odor was noted from the surface mat of suspended matter at a distance of about 50 feet. Sime slight odors were also noted from the heaps of scrapings deposited nearby, but no odors were noted that were sufficiently intense to be objectionable.

On the second detailed examination, about five months later, it was found that the efficiency of the plant was not so high as on the first examination, and that the poor quality of the effluent was largely due to poor distribution and to the fact that there was considerable laxity in the management of the filters, as indicated by the fact that in certain instances sewage has been allowed to flow onto one or more units for 30 hours or longer.

The experiments on the disinfection of sewage effluent carried out at Lancaster afforded considerable information as to the general character of the effluent from the plant during the period following the second detailed examination. Representative results at this plant indicating what may be accomplished in practice as regards the removal of bacteria from the crude sewage by its treatment on intermittent sand filters are presented in a supplementary report (See pages 733-734.)

On a visit made November 1st, 1906, it was noted that sewage tended to pond on the north side of the filters and that when two filters were being flooded from the same gate chamber, the lower filter generally received the more sewage.

It was observed that in the morning the effluent was very well purified; the turbidity was estimated at 15 parts per million and nitrates were present to the extent of 10 parts per million. In the afternoon the morning sewage had begun to reach the underdrains and the turbidity increased to 40 parts per million and in general the effluent had greatly deteriorated. These features suggest the intimate relation between the efficiency of the plant and the distribution of the applied sewage, and that the volume of sewage flowing directly from the institution is so small compared with the area required to handle the entire day's flow, that it is not possible to obtain a satisfactory and thorough division of the sewage over the entire area.

On the third examination of the plant, the new method of operation had prevailed for some time and in general had greatly improved the efficiency of the plant. The effluent was, of course, non-putrescible, but was perhaps not so thoroughly purified as might be expected from most efficient sand filters.

SUMMARY.

Evidence available from the three detailed examinations of this plant and from the other visits has shown that the sewage of the institution, in general, has been purified by the plant without nuisance and that the small brook has received practically no measurable pollution. Analytical data indicate that the effluent from the plant is generally of low turbidity, and that it contains sufficient dissolved oxygen and nitrates to insure its ultimate stability. As a result of this investigation, more attention has ben paid to the matter of operating the plant and the general tendency in this regard has been towards the use daily of more area and the application of sewage to the several filters strictly on an intermittent basis. The results of these changed operating procedures have been a decided improvement in the character of the effluent. The desirability of applying institutional sewage in doses, preferably by means of an automatic dosing device, has been strongly indicated by the study of this plant. The large area to be covered by the comparatively small flow of sewage renders it impracticable to obtain satisfactory division of the sewage over the entire area and results in localized clogging and decided depressions in the sand surface adjacent to the distributers. No difficulty has been experienced in operating the plant in the winter weather, even though the filters have been flat surfaced. In general the sewage of the institution has been successfully purified without nuisance.

COSTS.

The first cost of the plant was $8,900.

The operating costs are perhaps $30 per month, although the foreman's time is not wholly devoted to the operation of the sewage purification plant.

TABLE NO. 89.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts per Million.												
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspend'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Fats.
					Organic		Free Ammonia.	Nitrites.	Nitrates.						
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.			
			Crude Sewage.												
May 18, 1906.....	8:00 A.- 8:00 P.	.....	51	41	53.0	20.0	12.0	.....	.....	.....	143	95	.....	.....	.....
May 18-19, 1906..	8:00 P.- 8:00 A.	.....	33	23	70.0	24.0	23.2	.....	.....	.....	92	46	.....	.....	.....
Weighted Av'ge.		.....	42	32	61.5	22.0	17.6	.....	.....	.....	118	72	.....	.....	.....
Oct. 16, 1906.....	5:30 A.- 6:00 P.	.....	80	65	27.0	5.0	25.0	0.00	0.0	22	230	131	7	0.0	27
May 2, 1907.....	5:30 A.- 9:30 P.	67	75	24	7.0	5.4	25.0	0.01	0.0	42	153	134	48	2.7	11
May 2-3, 1907....	10:00 P.- 5:00 A.	66	18	10	6.0	4.6	10.0	0.02	0.0	10	.....	.....	7	5.9	.....
Weighted Av'ge.		67	47	17	6.5	5.0	17.5	0.02	0.0	26	.....	.....	28	4.3	.....
			Effluent Sand Filters.												
May 18, 1906.....	8:30 A.- 8:30 P.	.....	15	.....	4.1	.....	4.8	.....	.....	.....	.....	.....	.....	.....	.....
May 18-19, 1906..	8:30 P.- 8:30 A.	.....	9.4	.....	3.9	.....	4.2	.....	.....	.....	13	9	.....	.....	.....
Oct. 16, 1906.....	5:30 A.- 6:00 P.	.....	20.	.....	5.5	.....	3.5	0.16	10.0	18	86	.....	.....	3.1	....*
May 2-3, 1907....	5:30 A.- 5:00 A.	54	9.4	.....	3.8	.....	2.2	0.20	17.5	.....	5	.....	.....	7.5	*

(For additional analytical data, see report on disinfection experiments.) * Putrescibility = 0.

MANSFIELD STATE REFORMATORY.

The State Reformatory of Ohio is a few miles north of the city of Mansfield. The institution is located on a 200-acre tract of land, which drains into the Rocky Fork of the Mohican River, the small stream into which the effluent is discharged from the municipal sewage purification plant at Mansfield. The reformatory was built about the year 1896, and at that time a water supply and a sanitary sewer system were provided. The water supply is obtained from driven wells and the daily consumption is estimated at 60,000 gallons. On the basis of an average daily population of 820 (1907), the per capita daily water consumption is 73 gallons.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

To provide for the proper disposal of the sanitary wastes of the institution, there was constructed about 1,150 feet of 15-inch sewer, into which lead lateral lines from all of the buildings. At the end of 1907 there were 1,150 feet of 6-inch pipe and 2,290 feet of 8-inch pipe. The total length of sewers is about 4,595 feet, or 0.87 mile. Facilities for diluting the sewage of the population of the institution, which it was estimated would ultimately increase to from 600 to 700 persons, were so inadequate that in planning the sewers, a sewage purification plant was included in the design. Care was taken, moreover, to exclude cellar and roof water and these are, therefore, collected in a separate storm drain, which in part discharges southward and in part northwest towards Rocky Fork. A full report of conditions at the institution and a complete set of plans for its sewerage and for the purification of the resulting sewage were submitted to the State Board of Health for approval. The plans for sewage purification by means of intermittent filters were approved by the Board in July, 1896. In general terms, the plant as approved consisted of combined grit chambers, screens and dosing tank discharged by an automatic siphon and intermittent filters of fine gravel located on low land north of the main building of the institution.

EXAMINATIONS AND INSPECTIONS.

Eight visits were made to this plant. Detailed examinations were made on August 21st, 1906, and August 29th, 1907. Inspections only were made in 1906 on April 25th, and in 1907 on January 8th, February 15th, April 26th, May 31st and October 14th.

DESCRIPTION OF PLANT.

The site of the plant is 200 acres in area, the greater part of which is farmed by the inmates of the institution. One of the main buildings of the institution is about 1,150 feet distant and the nearest dwelling house is one quarter mile away. (See Plate XLIII.)

GRIT CHAMBERS.

The crude sewage which is conducted to the purification plant by gravity, flows first into an underground chamber 6 feet square in plan and 11 feet 6 inches deep to the crown of the arch roof. The walls are of brick 6 inches thick and the roof is a 12-inch brick arch. The bottom is of concrete 12 inches in thickness. This is primarily a gate chamber whereby the dosing tank which follows may be by-passed and wherefrom the flow of sewage may be diverted to either or both of the two sets of grit chambers and screens.

The grit chambers proper, two in number, are 18 inches wide, 30 inches long and 7 feet deep, and into them flows the sewage from the institution through a main 15-inch sewer. Each chamber has a capacity of about 200 gallons, equivalent to slightly less than three minutes average flow.

Screens.

The grit chambers, screens and dosing tank are entirely underground and cover an area 7 feet 8 inches wide and 17 feet 8 inches long. The screen chambers are each 2 feet 6 inches wide, 5 feet long and 6 feet deep. The walls are of 12-inch brick and the bottom is of 12-inch concrete. Flow through these duplicate chambers is controlled by a sluice gate. At this point the sewage is screened through a screen of No. 8 galvanized iron, diamond mesh, 5x2 feet 6 inches in plan, with a total area of 12.5 square feet. The clear opening is about ¾ inch. The screen is set horizontally and is so arranged that the sewage passes upward and the solid matters fall to the bottom of the chamber.

In the bottom of the screen chamber is a sluice gate, which allows the discharge of the contents of the chamber onto a second screen of ½-inch iron rods set with a clear opening of 1½ inches. This chamber is constructed of 8½-inch brick and is 2 feet 2 inches by 4 feet 3 inches in plan and 4 feet 5 inches deep. The screen is set vertically and is 3 feet 10 inches wide, 3 feet 5 inches high and has an area of 13 square feet.

Dosing Device.

The northerly end of the underground tank is used as a dosing chamber and is 6x9 feet 3 inches in plan and 14 feet deep and has a capacity of about 414 gallons per foot. The tank is provided with a 15-inch overflow, located at an elevation above that of the normal flow line, and a second mode of emptying which comprises an 8-inch drain which leads from the bottom of the siphon chamber. The latter is controlled by an 8-inch gate valve.

The tank is discharged by an 8-inch Van Rankin siphon. As originally constructed, this siphon was provided with an air valve which was controlled by a lever arm and weight operated by a float. Recently, (1907), this arrangement has been abandoned and the original air valve has been replaced by a ¼-inch whistle valve, to which is attached through pulleys a copper chain and weighted float so arranged that the lowering of the water causes the weight of the float to open the valve and thus vent the siphon.

Sludge Disposal Area.

No provisions were made in the original design to purify the sewage which is discharged when the upward flow screens are cleaned. In the fall of 1907, a sludge filter constructed of cinders was built directly over the sewer leading from the auxiliary screen chamber to the creek. This filter has an area of 25 x 40 feet and is 2 feet deep and is so arranged that the sewage discharged when cleaning a screen may be distributed upon it by gravity. The effluent flows into the creek at a point about 100 yards above the effluent from the filter.

Filters.

The sewage direct from the dosing tank flows through a main carrier laid in embankment and consisting of 18-inch vitrified sewer pipe. Several brick gate chambers are provided, each of which contains an 8-inch iron shear gate; from these chambers the sewage is diverted to the several filters through short lengths of 8-inch pipe. The filters are seven in number and comprise a total area of 1.1

acres. They are surrounded with earth embankments which contain the main sewage carrier.

Filtering Material. The filtering material was originally 5 feet in depth and consisted of crushed sandstone obtained from a neighboring quarry. The effective size of the upper foot of filtering material was 0.23 m. m. and the uniformity coefficient 1.7; at 3-foot depth these constants were 0.21 m. m. and 1.9 respectively. The sandstone filtering material contained also a large number of stones from 1 to 4 inches in size. At the end of 1907, the filtering material was considerably reduced by scraping and the average depth to the underdrains was 4 feet 5 inches.

Underdrains. The filters are underdrained with two main drains 8 inches in diameter provided with lateral lines of 4-inch vitrified sewer pipe laid with open joints at a distance apart of 20 feet. No lantern holes nor other means of ventilation are provided and no coarse material is placed over the underdrains. The main drains both discharge at a circular manhole 4 feet in diameter and 3 feet 6 inches deep closed with a wooden cover and located about 150 feet west of the filters.

Distribution Devices. The sewage is distributed from the several main carrier gate chambers by one line of 10-inch split tile 40 feet long on each filter. This tile is about 3 inches deep and extends from one corner to the center of a unit.

Effluent Discharge. The effluent from the filters flows by gravity through the 8-inch main underdrains through several hundred feet of 10-inch pipe to the creek. This pipe is laid on a grade of 1 to 700. The embankments around the filters prevent flooding during high water although there is little probable danger of serious floods.

SEWAGE FLOW.

Records of the number of times the dosing tank is filled daily have been kept on the two detailed examinations of this plant and these data have afforded information as to the quantity of crude sewage at the institution. On the first detailed examination the dosing siphon was out of order, but by temporarily closing the outlet it was possible to cause the tank to fill. On this visit, from 6:50 o'clock A. M. to 9:05 o'clock P. M. the tank filled 27 times corresponding to 58,400 gallons of sewage, or 67 gallons per capita, based on the population at that time of 875 persons. Subsequent data obtained on the second examination, however, gave more accurate information as to the capacity of the dosing tank and indicated that these figures are about 15 per cent. too high. On the second detailed examination, the dosing tank was in normal operation, and from 5:45 o'clock A. M. to 9:45 o'clock P. M. it was filled 37 times. The period of discharge ranged from 2.5 to 4 minutes, and allowing for the inflow of crude sewage during discharges, the total sewage flow for the above period was 68,000 gallons corresponding to 83 gallons per capita based on the population of 820. It was noted that there was 2 feet maximum variation in the depth of draw of the siphon. The flow of sewage at the institution practically ceases at about 9:30 o'clock P. M. except for a small volume of leakage. Practically no storm water reaches the sanitary sewers.

COMPOSITION OF CRUDE SEWAGE.

On the two detailed examinations, samples of the crude sewage were collected at the gate chamber at the entrance to the screen chamber. On the first examination, equal volumes of the sewage were collected at one-half hourly intervals. On the second examination, equal portions were collected during each filling of the

dosing tank, and by this method, the samples roughly corresponded to the varying rate of sewage flow. The analytical data indicate considerable suspended matter and a sewage which contains dissolved oxygen, but no nitrates and no nitrites. The results obtained on the second detailed examination are interesting on account of the large quantity of fats carried by the crude sewage. Detailed results of the analyses available during this investigation are appended.

OPERATION.

The operation of the plant is in charge of the architect and mechanical engineer of the institution. The actual operation of the filters is assigned to one of the prisoners, who is on duty from 7.00 o'clock A. M. to 3.45 o'clock P. M. each day. No pumping is necessary at this plant. The labor involved in its operation is that necessary in cleaning the filters and in changing the flow of sewage to the different units.

SCREENING.

The crude sewage receives a fairly thorough screening prior to its entrance into the dosing tank. As before stated, the screen is operated on the upward flow principle and to prevent clogging, means are provided whereby the material adhering to the underside may be flushed. Twice daily, in the early morning and in the middle of the afternoon, the valve is opened leading to the auxiliary screen and for a period of ten minutes, the sewage flow is thus by-passed. It is estimated that about 1,500 gallons of sewage are discharged at each cleaning. Only one set of screens have been used during this investigation. Such large quantities of crude organic matter are caught on the screen and discharged into the stream, that acting under advice from the State Board of Health, in the fall of 1907 there was constructed the sludge filter of cinders previously described. This filter receives the heavy sludge incidental to the cleaning of the screen.

DOSING TANK.

Until the summer of 1907, the siphon operating the dosing tank was out of order, and sewage was flowing directly onto the filters. It was found that the float provided originally with the filter did not cause the siphon to vent. On this account, early in the investigation, the State Board of Health advised that the siphon be replaced with one which would give positive results. The siphon is of the Van Rankin type and subsequent inspection showed that the trunions were unseated and that the moving trap was clogged with rags, and hence the normal function of the siphon could not take place. These obstructions were removed and in the summer of 1907 the new engineer of the plant of the institution devised a new air valve with suitable float control, as already described. The siphon thus modified has been in successful operation, and since the summer of 1907 the sewage has been applied to the filters in doses.

SAND FILTERS.

Since this investigation began, there has been a material change in the operation of the sand filters. On the first visit to the plant the filters were badly clogged and it had been the practice to maintain the surface of the filters in furrows throughout the year. The siphon in the dosing tank was out of order and sewage was continually applied to the filters and several furrows were in use at one time. After the winter of 1906, such serious clogging ensued that the underdrains were inspected and were found to be clogged. It was found that there had been such an extensive clogging that the organic matters had penetrated in places almost

to the underdrain tile. The underdrains were then reconstructed and the grade of the main drain was increased, as before mentioned, and at the suggestion of the State Board of Health, the filters were leveled and after a thorough cleaning the area was divided into seven distinct units formed by the coarse stones raked from the filters. It is of special interest to note that the deep trenches (18 inches deep) in use prior to this investigation in the absence of proper doses of sewage had eventually caused practically the complete clogging of the underdrains.

Following this overhauling of the plant, still in the absence of proper dosing, an attempt was made to operate the plant intermittently. One unit was in use daily and the filter in service was changed at about 4.00 o'clock P. M. each day. Under this mode of operation, sewage covered the surface of the filter about 6 inches. Before again being placed in service, the filters were allowed to drain and dry and were thoroughly raked. Practically similar conditions were found on the visit of January 8th, 1907. It was then noted that the surfaces of two of the filters were heavily coated with a heavy algal growth resembling *Spirogyra*. The visit of February 15th indicated that the method of changing the filters twice a day still prevailed. It was found that each filter was allowed to receive four applications of sewage during an elapsed period of eight days before cleaning. With seven filters in use, one would be cleaned about once in 28 days. The dosing siphon still continued to be out of service. With a view to eradicating the growth of algae, noted on the previous visit, it was suggested that copper sulphate be applied to the filters. It appears that, as suggested, two pounds of copper sulphate, contained in a cloth bag, were placed in the inlet at the corner of one of the filters, so that the flow of sewage would dissolve the chemical. This quantity of copper sulphate corresponded roughly to 10 parts per million. As a result of the application of copper sulphate, it was stated that the growth of algae disappeared in two days.

On the visit of April 26th, it was found that the operation of the dosing siphon had been normal for a few weeks. No change was made in the operation of the plant, but it was noted that the large dose of sewage afforded a greater opportunity for the filters to dry and tended to reduce surface clogging.

On the detailed examination of August 29th. 1907, it was found that a new caretaker was in charge of the plant and that it had been customary to allow the sewage to flow onto the filters until it practically refused to flow through the filtering material. This practice, of course, produced very poor results and brought about serious clogging. The attention of the officials was directed to this point and since that date two filters have been used each 24 hours. The application of the sewage in doses has continued, and as noted on the final inspection on October 14th, 1907, the operation of the plant has been normal for a sewage purification plant of this type. The clogging which has been so frequently in evidence has, of course, necessitated very frequent scraping and raking and has resulted in a decided reduction in the thickness of the filtering material. As already noted, the filtering material contains considerable coarse material and to facilitate the operation of the plant and to improve the efficiency, it is strongly desirable that the filters be resurfaced with a suitable grade of fine sand. Based on the average rate of 68,000 gallons the average rate of filtration is 62,000 gallons per acre in 24 hours corresponding to a population load of 745. (Population 820, 1907).

EFFICIENCY.

It is of interest to review briefly information available prior to this special investigation as to the efficiency of this sewage purification plant. Analyses of the effluent made in 1899 and in 1902, as reported in the special report of

the State Board of Health for the year 1903, indicated that the effluent of the plant was then clear and odorless and that the organic matter of the crude sewage was fairly well nitrified. The practice of maintaining the filters in deep furrows was found to cause decided clogging and necessitated considerable labor in cleaning the filters. It was noted also that the dosing device was not in successful operation and that there was a discharge of considerable organic material in the creek during the daily cleaning of the upward flow screen.

Screening.

The serious pollution of Rocky Fork by the practice which prevailed up to the fall of 1907, of cleaning the upward flow screen twice daily, has always been a criticism of the plant from the standpoint of the protection of the stream from sewage pollution. The screen has served to remove from the crude sewage no inconsiderable quantity of organic matter and as indicated by results of the analysis of samples collected on the second detailed examination in August, 1907, the screens removed about one-third of the suspended matter and further by virtue of the passage of crude sewage up through the clogged screen the sewage as applied to the filters contained slightly more organic matter than the crude sewage. The very high fats found on this examination in the sewage as applied to the filters are worthy of special comment.

The construction of the cinder filter for receiving the crude sewage necessarily by-passed during the cleaning of the screen has now prevented the pollution of the Rocky Fork due to this cause.

Filters.

On the first inspection, as before stated, the efficiency of the filters in the purification of the sewage of the institution was found to be very low, owing to a serious clogging of the underdrains and the entire filtering material. The first detailed examination in August, 1906, showed that the purification of the sewage was not satisfactory since sewage passed too rapidly to the underdrains, and since sewage was applied to the filters continuously and not in doses, conditions which resulted in poor distribution and a serious clogging in areas adjacent to the central distributor. Similar conditions prevailed until the dosing apparatus was repaired in May, 1907. A winter inspection of the plant on February 15th, indicated that the purification of the sewage was fair for winter conditions, but that the creek was being seriously polluted by the discharge of crude organic matter incidental to the cleaning of the screen. The inspection of May 31st, 1907, was the first after the dosing siphon was repaired and the effect of applying the sewage in regular doses was shown by a marked improvement in the character of the effluent and the condition of the filtering material. The large dose of sewage tended to afford a greater opportunity for the filters to dry, a condition which is, of course, essential in the matter of minimizing surface clogging.

Through the courtesy of the engineer of the institution on May 12, 1908, samples were collected of the strong sewage by-passed during the cleaning of the screen and a corresponding sample of the effluent from the cinder filter. The analytical data which are shown in the next table illustrate the highly polluting character of this liquor and also show that the sewage is now purified to a very satisfactory degree.

TABLE NO. 90.

Analyses of Applied Sewage and Effluent of Cinder Filter on May 12, 1908.

Constituents.	Parts Per Million.	
	Sewage.	Effluent.
Oxygen Consumed	182	17
Organic Nitrogen —		
Total	23.0	7.2
Dissolved	17.0	.....
Nitrogen as —		
Free Ammonia	25.0	2.8
Nitrites	0.00	0.00
Nitrates	0.0	14.0
Suspended Matter —		
Total	1,460	8
Volatile	970	3
Fats	320	.....
Putrescibility	+	0

On the detailed examination of August 29th, 1907, it was found that the plant was not in good condition. Although the sewage was being applied in doses, yet it was found that the new caretaker allowed sewage to flow onto one of the seven units continuously until the surface clogged so that the sewage could not pass to the underdrains. On the day of the examination a sample of effluent was collected from the filter, which had been in service for five days. The result of this continuous operation with the surface of the filters submerged during this period, was the production of a putrescible effluent containing considerable organic and suspended matter and one which showed no nitrification whatever. The attendant was advised to divert the sewage to a second unit and this was done at noon. From 5:00 o'clock P. M. until 9:30 o'clock P. M. samples were collected from the filter to which the sewage had been applied at noon, and as the appended analyses indicate, the effluent was greatly improved. The organic matter was decidedly reduced, as indicated by the oxygen consumed and nitrogen data, and nitrates were noted to the extent of 10.8 parts per million. A part of these nitrates, no doubt, were washed from the filter. It is evident from these facts that it is essential to pay careful attention to the feature of operating the seven units intermittently. Furthermore, as the effluent collected from 5:00 o'clock P. M. to 9:30 o'clock P. M. was slightly putrescible, it suggests that possibly the filtering material at this plant is so coarse, especially owing to the presence of large stones, as to admit of a too rapid passage of the sewage to the underdrains. To improve the efficiency of this plant and to facilitate its operation, it is advised that the original grade of the surface of the filters be restored by sand of suitable quality. The question of resanding the plant was discussed informally on a final inspection of the plant on October 14th, 1907. Subsequent to the daily examination in August, the filters have been operated strictly in rotation and although they were cleaned frequently it appeared that so much sand had been removed from the filters by scraping, since they had been in service, that the reduced thickness of the filtering material and especially its comparatively large size, prevents the proper purification of the sewage. Measurements of the

present grade of the filters were subsequently made by the architect and mechanical engineer. It was learned that about 7 inches of filtering material had been removed and that about 1,500 cubic yards were necessary to restore the filters to their normal original grade.

SUMMARY.

The general conclusions stated in the special report of the State Board of Health for the year 1903, relative to the efficiency of the sewage purification plant at the reformatory have again been brought out by the results obtained during this investigation. The absence of proper dosing facilities and the failure to prevent a lower efficiency by the intermittent operation of the several units has in a large part attributed to the failure of the plant to afford a proper purification of the sewage. The repairing of the dosing apparatus made a marked improvement in the plant, but negligence on the part of the caretaker has at times prevented the production of a sufficiently purified effluent. The officials of the institution have taken marked interest in the investigation and have endeavored to obtain the best results possible. The feature of the discharge of crude organic matter during the cleaning of the screen has been one of the chief points of criticism of the plant, but the construction of a cinder filter to receive this crude sewage, as carried out in the fall of 1907, has overcome this serious pollution of Rocky Fork. Under intermittent operation, provided the sewage is applied in doses, as has been true since the spring of 1907, present conditions indicate that the plant cannot produce an effluent of sufficient purity in view of the coarse nature of the filtering material, and it is highly desirable that the filters be resanded as already suggested. It is understood that this matter will be mentioned in the report of the superintendent relative to the appropriation for the year 1908.

COSTS.

The actual cost of constructing the plant is somewhat indeterminate in view of the fact that the labor was supplied by the prisoners. Exclusive of labor, the estimated cost of the sewers and the sewage purification plant was as follows:

Sewers to plant	$4,000
Screen chamber, dosing tank, underdrains and piping for filters	1,000
	$5,000

As true at many of the institutions in the state the operation of the sewage purification plant adds no expense to the general per capita maintenance. At this plant, one of the prisoners is detailed to the operation of the plant. The matter of repairing the underdrainage system and the construction of the sludge filter and other repairs and alterations made during the period covered by this investigation were carried out by prison labor, and no special record is available of the cost of the work.

TABLE NO. 91.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts per Million.														Remarks.
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspended Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.	
					Organic		Free Ammonia.	Nitrites.	Nitrates.								
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.					
Crude Sewage.																	
Aug. 21, 1906.....	7:00 A.-9:00 P.	77	98	....	7.8	.....	12.5	0.00	0.0	47	138	....	7.8	3.5	....	70	
Aug. 29, 1907.....	5:45 A.-9:45 P.	74	41	30	8.4	3.6	17.2	0.00	0.0	38	153	87	14.0	4.4	....	210	Air temp. 75°.
Applied Sewage.																	
Aug. 29, 1907.....	5:48 A.-9:48 P.	74	38	32	9.6	2.4	17.6	0.00	0.0	57	109	56	3.1	3.8	....	388	
Effluent Filters.																	
Aug. 21, 1906.....	7:00 A.-9:00 P.	73	49	....	6.6	.....	6.6	0.50	5.0	44	55	25	17.2	1.9	....	.....	
Aug. 29, 1907.....	7:30 A.-4.30 P.	73	26	....	7.0	.....	3.8	0.00	0.0	....	93	48	.....	2.8	+	.....	Sewage turned on clean dry filter at 11:50 a. m. Filter previously in service used 5 days; not entirely drained at 9:30 p.m. aft'r 10 hrs.
Aug. 29, 1907.....	5:00 P.-9:30 A.	73	11	....	5.0	.....	3.0	0.38	10.8	....	48	19	.....	3.8	+sl.	.....	

MASSILLON STATE HOSPITAL, MASSILLON.

One of the larger state hospitals for insane is two miles south of the city of Massillon on high ground which drains into a small tributary of the Tuscarawas River. The population of the institution in its early history was about 500, but has now increased to an average of 1,600 persons. When first built, a water supply was installed and comprised three driven wells from which water is drawn at the present time, with an estimated daily consumption of 250,000 gallons.

A system of sanitary sewers was built in the years 1896-1898 and comprises about 4,332 feet of vitrified sewer pipe which ranges in size from 6 to 10 inches. The location of the institution on high ground renders the drainage easy of accomplishment. The arrangement of the institution on the cottage plan naturally demands a considerable extent of sewers, which were formerly united in a main 10-inch pipe and led to a run which flows into the Tuscarawas River.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

Due to the rapid growth of the institution, it soon became apparent that the continued discharge of crude sewage into the adjacent run would give rise to a decided nuisance and hence plans were set on foot to purify the sewage. This plant was designed to treat the sewage of 1,000 persons and was used from about 1899 to the summer of 1907, when it was supplanted by a second plant, in view of the insufficient capacity of the early plant on account of the largely increased population of the institution. Plans for both plants were submitted to the State Board of Health for approval. The first plant approved in April, 1898, embodied a collecting reservoir from which the sewage discharged by a siphon flowed on to intermittent sand filters. The second plant was approved by the Board in June, 1906, on condition that its operation should be at all times satisfactory to the State Board of Health, and that its capacity should be increased in a manner satisfactory to the Board whenever this is deemed necessary by said Board. It comprises a screen, screen chamber, and dosing tank with devices for automatically discharging the same and for rotating the dose in turn onto the sand filters which complete the design.

The first plant which sufficed to care for the sewage of the institution in a satisfactory manner for several years after its construction, with the rapid increasing growth of the hospital soon proved inadequate and was a decided nuisance. In view of this fact, application was made to the legislature in 1906 and as a result an appropriation was made to provide for a new sewage plant of sufficient capacity to meet present requirements and arranged so that further extension could be carried out without serious difficulty. The two plants will be described in turn.

INSPECTIONS.

No examinations were made at Massillon, as the new plant was not in operation until the late summer of 1907. The old plant was inspected on April 18, 1906 and the new plant on July 19 and November 1, 1907.

DESCRIPTION OF FIRST PLANT.

The crude sewage from the institution flows by gravity through a screen chamber thence to the dosing tank and filters.

SCREEN.

The sewage is first screened in a basket screen which has a 1-inch open space. The basket is suspended vertically at the inlet end of the storage reservoir or dosing tank.

DOSING TANK.

The dosing tank or reservoir is built of brick. It is 15 x 40 feet in plan with an average depth of 5 feet 6 inches and a capacity of about 25,000 gallons. It is discharged by a 5-inch siphon through an inverted siphon consisting of about 400 feet of 10-inch vitrified pipe in 3-foot lengths. As this siphon was to be subjected to less than a 10-foot head, it was possible to use vitrified pipe.

FILTERS.

The original filters are four in number and each is about 100 feet square. The total area is, therefore, almost 1 acre.

Filtering Material. The filtering material consists of sand and gravel obtained from neighboring pits and has an average depth of 4 feet 6 inches. The construction of the filters is as follows: Directly over the underdrains there is placed a layer of coarse gravel 8 inches thick decreasing to 4 inches at points half way between the lateral drains. Over this coarse material is placed a 3-foot layer of finer gravel and upon this a layer of sand 12 inches in thickness. The filtering material in the upper 3 feet of the filter is of gradually increasing size from the surface to this depth. The effective size ranged from 0.30 to 0.90 m m. and the uniformity coefficient from 5.7 to 11.6.

Underdrains. In constructing the underdrainage system, the bottom of each filter is formed into depressions, the sides of which slope 6 inches in 25 feet. The depressions are 50 feet apart and in them is laid 4-inch tile on a grade of 1 foot in 500. These lateral lines lead to an 8-inch main underdrain.

Distribution Devices. The main sewage carrier for diverting the sewage to the different filters is a 6-inch pipe laid in the diverting embankment which is constructed from the soil excavated in building the filters. The surface distribution on the filters themselves is effected by a system of wooden troughs which are further assisted throughout the year by means of cross furrows.

Effluent Discharge. The effluent flows to the Tuscarawas River by gravity from the filters through a line of 8-inch vitrified sewer pipe 1,150 feet long. Supplementing the above filters there is available 20 acres or more of grass land adjacent to the plant. This area is at times flooded in accordance with the system of broad irrigation. The soil on this area is very fine and has an effective size of only 0.03 m. m. and a uniformity coefficient of 4.0. The subsoil has an effective size of 0.06 m. m. and a uniformity coefficient of 2.3. A manhole located in the sewer leading to the sewage plant proper provides means for diverting the sewage to the irrigation field; the further distribution of the sewage is effected by shallow earth ditches.

COSTS.

The cost of this plant was $9,255; and was divided as shown below. Only about $300 under the item of sewers could properly be charged to the sewage purification plant so that the actual cost of the work alone was about $5,500. This cost does not include engineering fees.

Sewers	$4,069
Reservoir	1,055
Filters	4,131
Total	$9,255

DESCRIPTION OF PRESENT PLANT.

The plant just described, was abandoned in the summer of 1907, when the new plant was placed in service. (See Plate XLIV.)

Screens.

The crude sewage conducted from the institution through an extension of the main sewer 3,150 feet in length and constructed of 12-inch pipe, is first screened through ⅜-inch round iron bars spaced 1¾ inches c. to c. and hence with a clear opening of 1 inch. The screen is 2 feet 11.5 inches x 3 feet 3.5 inches in size and has a total area of about 10 square feet. It is inclined 20° to the vertical. The screen is placed in a chamber 3 feet square and 3 feet deep constructed of brick with 8-inch walls and a 6-inch base. The 12-inch main sewer enters and leaves this chamber with its invert flush with the bottom. An 8-inch overflow pipe is provided on one side of the chamber with its invert 12 inches from the bottom.

Dosing Tank.

Direct from the screen chamber, without the intervention of a chamber for the interception of grit, the crude sewage flows into a dosing tank. This is built of reinforced concrete with walls 12 inches thick reinforced with two rows of ⅜-inch steel rods spaced 12 inches apart. The tank is 12 feet 6 inches x 25 feet in plan and 5 feet deep and has a capacity to the flow line of 8,200 gallons. The depth to the flow line is 3 feet 6 inches. The bottom of the tank is constructed of 8-inch concrete. The entire tank is covered with a concrete roof 6 inches thick reinforced with ½-inch steel rods spaced 4 inches apart; the alternate rods are bent up at the ends. A brick building, 11 feet 6 inches x 14 feet in plan and 8 feet 6 inches high to the top of the pitched roof incloses the tank. Entrance is effected through a 2-foot 10-inch x 6 foot 7-inch, ⅞-inch white pine door. The bottom of the tank contains 20 feet from the inlet end a sump 4 feet 3 inches in diameter and depressed 6 inches below the general floor level. This sump receives the main float of the discharging apparatus. The 12-inch main sewer from the institution enters the chamber with its invert 4 feet 5 inches above the bottom. The dosing chamber may be by-passed by the pipe in the screen chamber already described and also through a so-called irrigation manhole located on the main sewer line several hundred feet from the plant and leading to an extended area of cultivated land. The dosing tank is discharged by a 10-inch siphon, and the sewage is automatically diverted in turn to the four filters in service by a patented mechanism consisting of an iron cylinder with four ports or openings which lead to a respective discharge pipe. Inside this fixed cylinder is a moveable cylinder which contains one port only through which the sewage flows to the filters in turn. A change in the position of the open port, namely, ¼ of a circle, is accomplished by the rise and fall of a float which operates through a rack and pinion. The center rod of the float is provided with as many pawls as there are openings in the discharge chamber, and these pawls when the float rises, cause ¼ of a revolution of the inner cylinder; the shaft moves freely on the downward movement of the float. A second set of four filters may be operated at will by changing the openings in the diverting gate chambers described below.

Filters.

The purification of the sewage of the institution is carried out at the present time on 16 intermittent sand filters, which are 93 feet square with a total area of three acres. The filters are underdrained at an average depth of

4 feet 6 inches. On account of the peculiar local topography, the filters are divided into four groups of four filters each. The different units are separated by earth embankments formed by the top soil excavated during construction. As originally constructed, they were not seeded but at the present time a heavy growth of vegetation has developed and accomplishes the same purpose.

Filtering Material. The filtering material is a gravelly sand which ranges from 0.24 m. m. to 0.45 m. m. effective size and has uniformity coefficients from 1.8 to 6.0. These filters are constructed from the natural sandy gravel which was found on the site of the plant and is stated to be upwards of 100 feet deep. In addition to the stripping of the area for the removal of the loam and top soil and aside from the diversion of the area into 16 units by embankment, the only construction necessary was the placing of the underdrainage system. The range in size of the filtering material in the several filters is shown in Table No. 92.

TABLE NO. 92.

Mechanical Analysis of Filtering Material.

Filter Nos.	Effective Size.	Uniformity Coefficient.
1, 2, 3, 4, 5	0.42	3.9
6, 9, 13, 14	0.45	6.0
7, 8, 10	0.24	1.8
11, 12, 15, 16	0.25	2.9

Underdrains. Each filter is underdrained by two lines of 4-inch vitrified pipe. The two units on the south side of the plant and one in the center are drained by two lines of 5-inch pipe which lead to a 6 to 8-inch main drain which discharges into the canal. The underdrains are about 50 feet apart. The joints are covered with cheese cloth and in the trenches over the drains is a 6-inch layer of locally available gravel. At the intersection of each lateral drain and the main drain there is a lantern hole which comprises a 5-foot 6-inch length of 9-inch pipe which extends 10 inches above the surface of the filtering material.

Distribution Devices. Sewage from the dosing tank is conducted through two lines of 12-inch vitrified sewer pipe and one line of 10-inch pipe which is carried in the dividing embankment to four shallow gate chambers. These are 4 feet 7 inches in diameter and of concrete construction; each is provided with four hand operated shear gates. Each gate chamber controls the flow to four filters. A special feature of this plant is the peculiar arrangement of the filters in groups of four. By means of the four manholes which alternately receive the flow from the dosing tank, it is possible to flood four or more filters in rotation.

The distribution of sewage on the surface of the filters is effected by wooden distributors of changing cross section. The distributors extend diagonally across each filter and are about 60 feet long. The first section of the distributor is 5 feet wide and the second section 3 feet wide; both sections have a uniform depth of 6 inches. Shortly after the construction of the plant was completed, the wooden distributors were anchored to wooden posts driven 5 feet into the sand. No slabs are provided to prevent the disturbance of the sand at the point of discharge of the distributors.

Effluent Discharge. The purified sewage flows by gravity through several hundred feet of 6-inch pipe to the Ohio Canal. The plant is well removed from

dwellings and is admirably located in this respect. It is situated on high ground and there is practically no liability of danger from high water.

VOLUME OF SEWAGE FLOW AND CHARACTER OF SEWAGE.

Although no examinations were carried out by the State Board of Health during this investigation, from the records of the consulting engineers relative to the new plant, data are available as to the flow of sewage. These records indicate the present sewage flow (1907) to be 220,000 gallons in 24 hours, or 137 gallons per capita. Storm water from the roofs largely augments the flow in wet weather.

Information available from inspections and from analyses made by the State Board of Health prior to this investigation, indicate that the crude sewage is typical of that of institutions, in that it contains high suspended matters, is of a comparatively high temperature and generally contains considerable fatty matter and soapy wastes from laundry operations.

OPERATION.

The operation of the new plant is intended to be practically automatic. Four filters are used in rotation in 24 hours and each of the four receives from 5 to 6 doses daily at the rate of 10,000 gallons per dose, or about 55,000 gallons of sewage daily. This dose is sufficient to flood the filters to a depth of 2 inches. After one day's flooding the four filters in service are allowed to rest for three days. The rate of filtration on which the design was based is 73,000 gallons per acre per day, or on the basis of 533 persons per acre at the present time. When the population has ultimately increased to 2,000 the rate of treatment will be about 667 persons per acre or at a rate in 24 hours of about 94,000 gallons per acre.

EFFICIENCY.

On the first examination of this plant, shortly after it was first placed in service, the condition of the filters was in general poor, the distribution was faulty, conditions which were due largely to the fact that the automatic apparatus was not correctly adjusted. Another feature of criticism was the fact that the dividing embankment had not been seeded and heavy summer rains had washed considerable clay onto the surfaces of the filters. The porous nature of the soil, which for a depth of 100 feet or more exists as a sandy gravel, on this inspection absorbed all of the applied sewage so that none was flowing through the outlet of the filters into the Ohio Canal.

On the second visit the plant was in very much better condition, although the automatic apparatus was not entirely adjusted. The need for supervision even in the face of the automatic nature of the operation of the plant was strongly brought out on this visit, especially since the inefficiency of the dosing apparatus was in part due to the fact that the moving parts had not been oiled and the fact that the apparatus had been entirely neglected.

SUMMARY.

Indications from the two inspections of this plant made during the short period of its operation have indicated that the design is such that the sewage of the institution will be purified to a satisfactory degree for sometime to come. The poor condition of the plant in the early history of its operation and especially

the lack of supervision suggest how dependent is the success of a plant upon the operation of the automatic devices which are intended to allow the operation of the plant without the intervention of human agency.

Another instructive point was developed relating to the strong desirability of insisting on the seeding or sodding of embankments in the case of sand filter construction. Unless this provision is made a part of the contract, early in the operation of the plant heavy rains will tend greatly to impair the filtering material as every opportunity is afforded for the deposition of clay upon the surface of the filters. While the new sewage plant at the institution is operated by one of the foremen in connection with other duties, it would be desirable, however, that an attendant be appointed, especially to superintend the operation of the plant, even though its operation is essentially automatic in character.

COSTS.

The sum appropriated by the state legislature for the construction of this plant was $8,000. The cost of the plant in detail cannot be given. Labor for excavation was one of the principal items and was performed by inmates.

STATE INSTITUTION FOR FEEBLE-MINDED YOUTH, MORGANS.

Near the village of Morgans, about 15 miles southwest of Columbus on the banks of the Big Darby Creek, is a branch of the State Institution for Feeble Minded. The institution contains one main building, together with a laundry, power house, and several farm buildings, and is on high land, a part of a 200-acre farm owned by the state. The institution was built in 1904 and at that time arrangements were made for modern sanitary conveniences and a system of sanitary sewers. The proposed plans were presented to the State Board of Health for approval. The plans for sanitary sewers provided for some 1,600 feet of 8-inch pipe arranged as an inverted siphon, which had a difference in the level of the two ends of 13 feet. A screen chamber and a storage chamber at the mouth of the siphon completed the sewer system as planned. This system then as at the present time received sewage only from the main building of the institution. In designing those sanitary sewers, it was recognized that some form of purification would be necessary in view of the small flow of Big Darby Creek and the necessity for preventing a local nuisance. Accordingly, the plans as presented contained the further provision for eight filters to be operated on the intermittent basis and to be constructed of natural gravelly soil available on the proposed site from which only a few feet of top soil would have to be removed.

The Board approved the plans for the sewers and the sewage purification plant which was to comprise one acre of gravelly filters, but called the attention of the superintendent to the importance of providing a proper dosing tank and of laying underdrains in case the sewage did not drain away satisfactorily from the surface of the filters. The population of the Home when first built was only about 50, and consequently the entire plant as proposed and approved was not constructed. Instead, three 0.1 acre units were built and these now serve a present population of about 265.

INSPECTIONS.

This plant was visited for inspection on Nov. 29, 1907.

DESCRIPTION OF PLANT.

The screen chamber and the storage tank are near the main buildings, and the plant proper is located on low land near Big Darby Creek about 1500 feet distant from the institution.

Screens.

The crude sewage is first received in a chamber 4 feet 6 inches square in plan and 7 feet 4 inches deep, in which the main sewer enters 2 feet from the bottom. At one side of this chamber, 3 feet from the bottom, a screen is provided composed of ⅜-inch iron rods ¾-inch apart in the clear. The screen has a total area of 1.4 square feet and is set vertically.

Storage Tank.

A 12-inch concrete wall separates the screen chamber from a storage tank of concrete 24 feet 4 inches long, 10 feet wide and 8 feet 6 inches deep, with a capacity of about 14,000 gallons. The tank is entirely of concrete construction with 12-inch walls and 9-inch bottom. It is covered with an arched roof of concrete which is surmounted with gravel. It is made accessible by a ladder through a 23-inch manhole which is covered with a ringed iron plate.

Sewage from the screen chamber flows into the storage tank through an opening 14 inches square located about 4 feet from the bottom. The outlet of the tank is the 8-inch iron pipe siphon, one end of which is 3 inches from the bottom of the tank.

Inverted Siphon.

From the storage tank the sewage flows directly into the inverted siphon, thence on to the intermittent gravel filters. An 8-inch gate valve is provided on the siphon line near the storage tank, which allows the latter to be filled to develop a head with a view to dislodging clogged material in the siphon line. Two other 8-inch gate valves and tees are provided for irrigation purposes along the siphon line.

Filters.

Three intermittent coarse gravel filters have been constructed by removing the top soil from the natural soil on the site of the plant. Each is 30 x 152 feet in area, or 0.1 acre, with a combined area of 0.3 acre.

Filtering Material. The filtering material is a very coarse gravel which contains a number of large stones. It is underdrained at a depth of 2 feet 6 inches.

Underdrains. The underdrains comprise one main 6-inch vitrified sewer pipe into which discharge at right angles three rows of 4-inch soft agricultural tile.

Dosing and Distributing Devices. The filters receive the direct discharge from the siphon without provision for applying the sewage in doses. The main carrier, which is merely an extension of the siphon, is provided with nine 8-inch gate valves, one for each unit. From the main carrier there branch 8-inch pipes, about 12 feet long, which pass through the dividing embankments and discharge on to the filter at an elevation about 18 inches above the surface. No other means of distribution are provided

Effluent Discharge. The effluent from the filters flows through about 100 feet of 6-inch vitrified sewer pipe on to the surface of the ground about 600 feet from the banks of the Big Darby. At this point there appears to be a considerable

area of coarse gravelly soil which allows the effluent to disappear so that it does not flow into the creek in a full stream. Apparently, the plant is so located that there is little danger from floods. The top soil removed during construction is used to form protecting levees which separate the three units already built. These levees extend from four to five feet above the level of the filtering material.

SEWAGE FLOW.

No examinations were carried out at this plant, but through the courtesy of the superintendent and the chief engineer of the institution, on Thursday, December 12, 1907, there was obtained a gaging of the sewage flow for a period of 12 hours beginning at 6:00 o'clock a. m. These measurements were effected by closing the outlet of the storage tank and noting the rate of rise of sewage in the tank at half hourly intervals. The total flow for this period was practically 14,000 gallons, which corresponds to a per capita flow of 53 gallons. The water consumption at the institution is no doubt somewhat greater, since the above figures do not include the water used in the boilers nor that consumed in the laundry which is sewered directly into Big Darby Creek. During rainy weather also, the flow is probably higher than the above, since rain water from the roof of the main building flows into the sanitary sewers for flushing purposes.

EFFICIENCY.

On the single visit to this plant there was prepared a full description, and there were made observations as to methods of operation and as to efficiency. Only three filters were originally prepared for use. On the basis of the daily flow of 14,000 gallons, the average rate of filtration for the entire available area would be about 47,000 gallons per acre per 24 hours. As actually operated, however, only one of the 0.1 acre filters has been in service and usually for a period of 3 months, so that the actual rate of filtration which has prevailed at this plant is about 141,000 gallons per acre in 24 hours.

When inspected the plant was in very poor condition. The surface of the filter in service was covered with sludge and with a heavy rank growth of vegetation. The need for more thorough distribution was very noticeable, as the sewage, flowing directly from the institution in a small stream, covered but a limited area of the filter and consequently caused a decided clogging. The effluent from the plant was foul, ill-smelling, and putrescent. As it passed through and over a considerable area of sandy soil before reaching Big Darby Creek, it is probable that it eventually became purified to a sufficient degree to prevent criticism in this regard.

In view of the above condition of the plant and the fact that at the present time it is attempted to purify the sewage of the institution at the rate of about 2,650 persons per acre, it is advised that the construction of the fourth filter already begun be completed and that in addition still another area be provided so that the total area of filters will be 0.5 acre. After this recommendation is carried out and also during the interim, it is advised that the filters be operated in daily rotation. It would further be advisable to rake the filters occasionally and keep them free and clean from vegetation.

Although the efficiency of the plant is low when judged from the standpoint of successful sand filtration, yet it is true that the local feature of the further purification of the effluent on the sandy bottom land affords sufficient purification to correspond to local requirements.

No information is available as to the original cost of this plant. It was designed by a former superintendent and was constructed entirely by the labor of patients.

TOLEDO STATE HOSPITAL.

The Toledo State Hospital is several miles west of the city of Toledo and lies on a slightly elevated strip of land which drains into Swan Creek. A water supply was provided and some sanitary sewers were built in 1885, when the hospital was established. At the present time, water for washing is obtained from the city of Toledo and for drinking, from driven wells. The daily water consumption is said to be in the vicinity of 700,000 gallons.

The institution is one of the largest of its kind in the state and averages about 1,750 patients. Including the employees, the population may safely be estimated at 2,000 persons. The rapid growth of the institution made necessary an enlargement of the sanitary sewers, as first built, and in 1897, there was installed a new system which comprised 2.42 miles of vitrified pipe which ranged in size from 4 to 12 inches. In addition to these strictly sanitary sewers considerable storm sewerage was planned. These storm sewers, however, are in part used for sanitary purposes since they receive domestic sewage from certain of the buildings which are so located that a gravity discharge into the regular sanitary sewers is not possible.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

Prior to 1897, all of the sanitary sewage of the institution flowed directly into Swan Creek. The dilution afforded by this stream, however, was insufficient to dispose of the crude sewage of the hospital in this manner, without a decided nuisance. Particularly obnoxious were conditions on low land a short distance below the institution. To avoid a continuance of this marked case of stream pollution, plans were set on foot to purify the sewage of the hospital. The plans for new sewers and a purification plant were submitted to the State Board of Health and were approved by the Board in January, 1897. In general, the design called for the purification of the sewage on an irrigation field suitably underdrained and arranged for the raising of crops.

EXAMINATIONS AND INSPECTIONS.

Visits to the hospital were made in 1906, on March 29, May 29-June 1, and Nov. 20; in 1907, on Feb. 13, May 17 and Oct. 25. All visits were inspections except that of May 29-June 1, 1906, when there was made a partial examination of the sewage purification plant.

DESCRIPTION OF PLANT.

The sewage purification plant for the institution is on a tract of land 23 acres in area and located about three-eighths of a mile east of the institution on low land which borders on Swan Creek. The nearest house is about 660 feet distant. The sewage reaches the plant by gravity, as there is considerable fall from the main buildings to the site of the plant.

SCREENS.

In the original design a screen chamber was provided constructed of brick with 12-inch walls and bottom. This chamber is 4′ x 6′ in plan and 5 feet deep at the inlet and 3 feet at the outlet. The 12-inch main sewer enters with its invert 6 inches above the bottom and leaves with its invert flush with the bottom of

the chamber on the center line. At the side of the tank a second 12-inch sewer with its invert 6 inches above the bottom leads to a collecting tank for the purpose of storing sewage for the irrigation of farm land, located at a considerable elevation above the main line of sewers. The outlets of the chamber are closed by 12-inch lipped iron shear gates. The chamber slopes 4 inches sides to center line. The screen originally provided has not been used for some time and during this investigation this screen chamber has been used as a weir chamber. It is covered with a hinged wooden roof of 2-inch lumber. Considerable heavy suspended matter is intercepted by the screen chamber, as now used for gaging the flow, but no provision was originally made for the interception of grit.

FILTERS.

The sewage purification plant comprises 23 acres of sandy loam. Of this area, 6.92 acres are divided into 16 units which range in size from 0.17 to 0.76 acre. The 16 units are separated by earth embankments which contain the main sewage carriers.

Filtering Material. The filtering material is a fine clayey sand and is the natural soil found on the site of the plant. The effective size ranges from 0.02 to 0.04 m. m. and the uniformity coefficient from 5.2 to 8.5. In preparing this area, the several units were underdrained to a depth of from 3 to 4 feet.

Underdrains. The underdrains comprise a main drain of 10-inch pipe, laid on a 0.4 per cent. grade, with lateral drains 3 inches in size constructed of soft land tile and laid 16 feet apart; the joints were wrapped with muslin. Occasional depressions have formed over the line of laterals and in these cases, especially in two of the filters, the filtering material has been removed and has been replaced with coarse cinders to depth of about 2 feet.

Dosing Devices. The filters are flooded by the gravity flow from the main sewer of the institution.

Distribution Devices. At a manhole below the second chamber, already described, there are two lines of 12-inch vitrified sewer pipe, one to supply sewage to the lower tier of filters, and the second to carry the sewage to the upper tier of filters. There are three brick manholes, one at each change of grade. From the manholes, 8-inch pipes controlled by iron shear gates lead to two or four filters. The lower carrier similarly has two gate chambers.

The sewage from a given gate chamber flows through 8-inch pipes on to one corner of a filter where a pile of stones has been placed to prevent the undue disturbance of the filtering material during flooding. Two of the filters are located about 1,000 feet from the main portion of the plant and to supply these a special outlet is provided in the manhole near the screen chamber.

Effluent Discharge. The location of the filters in terraces and on land somewhat lower than the site of the main building of the institution, permits a gravity discharge. There are two outlets into Swan Creek. The one for the main set of filters comprises about 75 feet of 10-inch pipe which terminates at the bank of the creek at an elevation about 12 inches above mean low water. The second outlet is provided for the two filters located near the screen chamber. At a gate chamber about 400 feet below the screen chamber on the main carrier line which supplies the lower tier of filters, means are provided for by-passing the entire sewage flow. It is of interest to note that a rise of only 12 inches in the creek practically places the plant out of service, as only one outlet is provided for both the lower and upper tier of filters. To prevent its complete inundation, a back flooding gate has been installed on the main underdrain line near the point of discharge from the main plant.

SEWAGE FLOW.

Weir measurements were made at half hourly intervals on the 24 hour test on May 31-June 1, 1906. The average, maximum and minimum rates of flow from these observations were 280,000, 380,000 and 191,000 gallons respectively. The average flow per person tributary was 140 gallons. The maximum flow occurred from 7:00 to 8:30 o'clock A. M. and the minimum at 1:00, 2:30 and 4:00 o'clock A. M. The high per capita sewage flow and especially the high night flow indicates a considerable needless waste of water, although certain of the cottages are equipped with automatically flushed closets which are in general use for institutions of this type. The above figure, moreover, does not include a certain volume of sanitary sewage which is admitted into the storm sewerage system.

From July to September 1906, inclusive, and from May to July 1907, inclusive, daily weir readings were made at 10:00 o'clock A. M. by the attendant at the plant. These records indicate that the maximum flow at this period of the day is about 363,000 gallons, the minimum flow from 165,000 to 297,000 and the average flow in the vicinity of 300,000 gallons, or 150 gallons per capita.

COMPOSITION OF CRUDE SEWAGE.

One analysis of the crude sewage is available from an average sample collected at half hourly intervals for 16 hours on November 20, 1906. The analysis of this average sample for the day and a part of the night period suggests a sewage of moderate strength. Observations made during inspections, however, indicate that in the day time the sewage is strong, contains considerable soapy matter and grease and is ordinarily of a high temperature which the daily records indicate to range from 61 to 84 degrees F. Large quantities of coarse excrementitious matter are generally visible since the grade of the main sewer is such that little opportunity is afforded for disintegration.

OPERATION.

The chief engineer of the hospital has general supervision over the operation of the sewage purification plant. Since May 1, 1906, a former patient has been employed to operate the plant and has given his entire time to this work. No sewage is pumped to the filters proper and during this investigation none was pumped to the auxiliary area situated at a higher elevation than that of the sewers. For the purposes of this investigation, during a part of the spring and summer of 1906 and 1907, daily records were kept of the temperature of the air and of the crude sewage, one daily measurement of the rate of sewage flow, a record of the number of filters in service and notes suggesting unusual features relating to the operation of the plant.

Conditions at Beginning of Special Investigation.

On the first visit on March 29, 1906, the sewage of the institution was not being purified and was caused to flow directly into Swan Creek. It was learned that the operation as carried out in the previous summer and fall was to flood one or more of the 14 filters in the day time and in the night from 5:00 o'clock P. M. to 5:00 o'clock A. M. to cause the sewage to flow on to the two areas adjacent to the pumping station. It was the practice to crop the filters with corn and no more sewage was applied than could be disposed of without injury

to the crops. At times it was stated that sewage was pumped to other land which was under cultivation.

Conditions During Investigation.

On the second visit the plant was in full operation. Shortly after the first visit, the superintendent and chief engineer took marked interest in the plant, and in an endeavor to place the filters in serviceable condition caused them to be plowed, cross-plowed and harrowed. In addition, repairs were made to several of the embankments and each filter was numbered by a suitably marked stake, which was set into the ground upon the adjacent embankment. The filters were all carefully measured and there was prepared a blue print which showed the arrangement of the filters and the area embraced by each.

The method of operation then practiced was first to cause the sewage to flow into the 50,000 gallon storage tank. This tank was newly bricked up and was reroofed. Some six to eight hours were required to fill the tank. When full, the sewage was discharged on to one of the filters. At times it was stated that a filter would receive two or three successive doses of day sewage, that is, the same filter would be dosed two days in succession, provided the surface had thoroughly dried during the night. From 5:00 o'clock P. M. to 5:00 o'clock A. M. it was stated that the sewage was applied on alternate nights to filters Nos. 1 and 2, which are adjacent to the dosing tank. When these filters were in operation, they received the direct flow from the institution. In view of the possibility that some of the filters under day operation were being too frequently dosed, it was suggested that it would be wiser to adopt a strict rotation in the flooding of the filters and that one filter should receive a single dose only. It was also suggested that it would be better not to crop the filters as in such cases the purification of the sewage is usually a secondary feature to the raising of a satisfactory crop.

The inspection of November 20, 1906 was made at a time when there was an unusual rainfall and the collection of samples of the effluent was not possible as the water in the creek had backed up into the underdrains. But few changes were indicated as regards the general method of operating the plant, but it was noted that previous recommendations had in general been carried out and that considerable attention was being paid to the care of the plant. The filters were in good condition and the sewage passed so readily through the sand that there appeared to be no reason from this standpoint why the plant could not be satisfactorily operated under winter conditions. It was learned, however, that in the winter season Swan Creek is very frequently in flood, its waters back up into the underdrains and prevent the passage of the sewage, a fact which tends to produce stagnation and a general foul condition of the surface of the filtering material.

The plant appeared in such good condition that the Board suggested that it be operated during the coming winter. When inspected, however, on February 13, 1907, it was found that the sewage was flowing directly into the creek and the condition of the ice in the creek adjacent to the outfall sewer indicated that the sewage had been discharged without treatment for some time. It was observed that the four filters located nearest the bank of the creek to a distance of from 4 to 5 feet above the embankments were covered with ice left by the receding water of a January flood. An attempt was made to operate the plant, but it was placed out of service in January and the advent of cold weather following shortly afterwards caused the water to freeze in the underdrains and practically rendered the filters impervious to sewage. The plant was by-passed in this manner from the middle of January 1906 until about April 1, 1907. When the plant was again operated the filters were plowed and thoroughly harrowed, and

following suggestions made during this investigation, the intermittent plan of operation was followed as closely as possible. At times, however, the dosing tank was not used and sewage was applied to the filters under the direct flow from the institution. On the final inspection on Oct. 25, 1907 the general method of operation was practically as heretofore. In some of the filters depressions were noted over the underdrains and in such cases the tile has been dug up and relaid with a covering of cinders about 2 feet in thickness.

The rate of operation during the day time when sewage is applied to the 14 filters farthest from the institution for 12 hours, is 60,000 gallons per acre in 24 hours. The night rate of filtration when two units only are used for the 12 hour period is about 200,000 gallons per acre in 24 hours. The total area of filters at this plant corresponds to a tributary population per acre of about 290.

EFFICIENCY.

Although no samples of the effluent have been examined during this investigation, yet it is indicated from inspections that when in service, the effluent from the plant is well purified. The greatest criticism to be attached to the plant is the feature of by-passing the sewage in the winter months. This condition is not due to negligence on the part of the operator, but appears to be attributable to the location of the plant and especially to the fact that a common outlet is provided for the upper and lower tier of filters. It would undoubtedly be a decided advantage and would no doubt enable the sewage to be purified during the winter months were there constructed a separate outlet for the upper tier of filters. Notwithstanding the fact that crude sewage is by-passed without treatment during the three colder months of the year, yet during this investigation no complaint has been formally lodged regarding odors nor other objectionable conditions along the shores of Swan Creek below the plant. There is another point which deserves decided criticism and that is the fact that the sewage from the administration building, the laundry and the boiler house does not flow into the sanitary sewers, but into the storm water sewers which flow into Swan Creek underneath the bridge a short distance below the plant. This practice, of course, seriously pollutes the creek throughout the year.

SUMMARY.

At the beginning of this investigation the sewage plant was in poor condition, and in previous years its operation and maintenance was viewed primarily from the standpoint of a successful crop and not from that of the purification of the sewage of the institution. Due to the interest of the superintendent and the chief engineer, early in this investigation the plant was overhauled and was placed in better condition than had prevailed for several years past. The plant has been well managed during 1906 and 1907 and its operation during the spring, summer and fall is all that could be desired. Even in the summer months, however there prevailed the objectionable direct flow of domestic sewage into the storm sewers and it is strongly recommended that this practice be discontinued. Winter operation of the plant has not been feasible since it was first built, owing to the flooding of the underdrains even with a small rise of the creek and the further fact that cold weather which usually follows a winter flood causes a freezing of the outlet piping, so that even after the floods have receded, sewage cannot filter through to the underdrains with sufficient rapidity to prevent ponding and stagnation. As a remedy for this condition, it is suggested that a separate outlet be constructed to drain the upper tier of filters so that a part of the plant at least may be available for use in the winter season.

In conclusion it is to be observed that a special employee was engaged to look after the plant, beginning about May 1906. The wisdom of this step has been shown by the improved appearance of the plant and the more satisfactory purification of the sewage of the hospital.

COSTS.

The first cost of the plant was only $3,000, but for the sake of comparison this figure is of no value as it includes material alone, since the plant was built entirely by the labor of patients. Operating expenses comprise only the salary of the caretaker at $25 per month or $300 per annum. The cost per annum per person tributary is 15 cents.

TABLE NO. 93.

Results of Chemical Analyses.

Date 1906.	Hour of Collection.	Temp. Deg. F.	Parts per Million.											
			Oxygen Consumed		Nitrogen As					Chlorine.	Suspend'd Matter.		Fats.
					Organic		Free Ammonia.	Nitrites.	Nitrates.				
			Total.	Dissolved.	Total	Dissolved.					Total	Volatile.	
			Crude Sewage.										
Nov. 20, 1906....	7:00 A.–11:00 P.....	65	112	.....	10.0	3.8	15.2	0.00	0.0	124	102	39	26

WAYNE COUNTY CHILDREN'S HOME.

This institution is in Wayne County, two miles north of the city of Wooster. It provides a home for between thirty and forty children. Including employees, the average population of the home is about 50. When the institution was founded in 1881, arrangements were made for a water supply and means were provided for the disposal of sanitary wastes. The source of water supply is a driven well from which water is pumped by power furnished either by a windmill or by a gasoline engine. The daily water consumption is estimated at from 900 to 1,200 gallons. Modern sanitary conveniences were installed in 1900 some nineteen years after the opening of the home and the sanitary sewers then built and as now existing comprise about 700 feet of 8-inch vitrified pipe.

CONDITIONS LEADING TO SEWAGE PURIFICATION

This institution lies only two miles north of the city of Wooster, and drains into Christmas Run, thence through a county ditch to Killbuck Creek, from which is obtained a part of the water supply of the city of Wooster. In view of the above conditions, it was distinctly necessary to provide for as thorough purification of the sewage as possible so that when the present sewers were constructed, plans were set on foot to purify the sewage. These plans were not officially approved by the State Board of Health. The plans adopted, for the purification of the sewage of the home, comprise screening, a dosing tank and two sand filters of artificial construction.

EXAMINATIONS AND INSPECTIONS.

During this investigation, this plant was inspected on April 13, 1906, July 13, 1906 and Oct. 19, 1907. No detailed examinations were made.

DESCRIPTION OF PLANT.

This small plant is about one-fourth mile from the main buildings of the institution on about 82 acres of land owned by the county.

Screening.

Sewage from the institution flows into a basket screen constructed of ½-inch iron rods which have a clear opening of three-fourths inch. The basket is practically square in section and its dimensions are 18″ x 18″ in plan and 24 inches deep. The superficial area is about 14 square feet. The basket is suspended vertically at the inlet end of the dosing tank.

Dosing Tank.

After screening, the sewage is stored in a dosing tank 7′-4″ x 15′ in plan and 6 feet deep, with a depth to the flow line of 3 feet 8 inches and a capacity of about 3,000 gallons. The tank is constructed of brick with walls 8-½ inches thick. Two manholes are provided, one over the inlet, and the other over the outlet. The manhole over the inlet is 22 x 21.5 inches in plan and is closed with a wooden cover. The other at the outlet is 2 feet 8 inches in diameter and 8 feet deep and is covered with a perforated iron manhole plate. At the outlet end of the tank, there is provided a 6-inch overflow which leads into the manhole. The overflow

is 4 feet above the bottom of the tank, and 4 inches above the normal flow line. The tank is discharged by a single 6-inch siphon set to draw 3 feet 8 inches. From the tank the sewage flows through about 400 feet of 6-inch pipe to the filters.

FILTERS.

The two sand filters are each 36 x 36 feet in plan, or 0.03 acre, with a total area of 0.06 acre. They are separated by earth embankments and are surrounded by a low wooden fence.

Filtering Material. The filtering material comprised originally 12 inches of fine sand supported by 2 feet of gravel. The sand was obtained from some distance, but the gravel was found practically at the site of the plant. The sand has an effective size of 0.15 m. m. and a uniformity coefficient of 2.0. The original depth of the sand has been reduced by scraping to 10 inches.

Underdrains. The filters are underdrained with lateral drains of 4-inch vitrified sewer pipe and are laid with open joints. There are two lateral lines in each filter, located 15 feet apart. No lantern holes nor other means of ventilation are provided. The lateral lines discharge into a main drain of 6-inch sewer pipe.

Distribution Devices. The 6-inch discharge from the siphon chamber enters a manhole at the filters one foot from the bottom. This manhole is 3 feet square and 3 feet deep and is constructed of brick 8-¼ inches thick. Flush with the bottom of the manhole is a 6-inch outlet pipe which is used for flushing the underdrains. The outlet leading to the filters is located with its invert 24 inches above the bottom of the gate chamber and hence 12 inches above the invert of the inlet pipe. The outlets from the manhole are controlled by iron shear gates. From this manhole the sewage flows into a shallow gate chamber 2 feet 6 inches in diameter and 18-¾ inches deep, constructed of brick plastered with mortar. The manhole is provided with two 6-inch iron shear gates which control the flow to either one or both of the filters.

The distribution of the sewage on the filter proper is effected by a wooden carrier constructed of 2-inch yellow pine of diminishing cross section as follows:

10 feet 14-⅝ inches wide and 10 inches deep.
10 feet 5 inches, 10-⅝ inches wide and 8-⅝ inches deep.
10 feet 5 inches, 6-½ inches wide and 4 inches deep.

At the change of section of the distributors, wooden slabs are provided; those on the sides are 3 feet square and those on the end 3 x 4 feet 8 inches in area.

Effluent Discharge. The effluent from the filters flows by gravity through a 5-inch vitrified sewer pipe about 152 feet long and laid on a 0.76 per cent. grade. There is a low embankment surrounding the filters, but the probability of floods is remote. It is of interest here also to note that the main carrier from the siphon chamber is laid on a rising grade from about mid-way between the dosing tank and the distribution manhole already described. This was made necessary on account of the impracticability of a creek crossing without prohibitive costs.

SEWAGE FLOW AND COMPOSITION OF CRUDE SEWAGE.

There were made no detailed examinations at this plant, but the sewage flow is estimated from information furnished by the superintendent, as to the water consumption. It is stated that the volume of water used daily ranges from 900 to 1,200 gallons or between 18 and 24 gallons per capita. Depending upon

the use of the laundry and bathing, the siphon tank is said to discharge from three to four times weekly.

An inspection of the sewage indicates that it is strong and has the usually soapy appearance of institutional sewage.

OPERATION.

The superintendent of the institution has general charge of the plant. It was formerly the usual practice to alternate the filters on successive doses, but as found on the final inspection, only one filter has been in service during the greater part of 1907. The filters are raked and cleaned occasionally and generally appear to be in good condition. In the spring of 1906, one of the filters was resanded and about 7 cubic yards of sand is said to have been removed. It was replaced by a like quantity of sand somewhat coarser than the original. The filters are operated at a rate of from 17,500 to 35,000 gallons per acre per day, depending upon the use of one or both filters. The entire area of filters corresponds to a load of 833 persons per acre. The filters do not clog and it is stated that it has not been necessary to by-pass the plant since built. The plant is operated with little difficulty except that during the wet weather of spring there is some leakage from the brook into the main sewer at the brook crossing. The considerably increased flow of sewage at such times tends to interfere with the normal operation of the filters.

EFFICIENCY.

No analyses are available to indicate by chemical evidence the character of the purification effected by the plant. An inspection of the effluent and of the brook at the outlet of the effluent drain indicates that the purification effected is very satisfactory although the population load is somewhat high. All available information from the three inspections strongly indicates that this plant serves to protect the water supply of the city of Wooster from organic pollution by the sewage of this small institution aside from the question of infection by chance pathogenic organisms.

COSTS.

From information obtained from the superintendent, the total cost of construction was about $1,550, including the sanitary sewers and the purification plant. The several items of cost are as follows:

Sewers, dosing tank and filters	$425.58
Filtering material, (Sand)	31.65
Labor and teaming	770.43
Engineering	290.00
Total	$1,547.66

There are practically no ordinary operating expenses. The superintendent estimates that perhaps $25 per year would cover incidental expenses of operation.

OHIO SOLDIERS' AND SAILORS' HOME, SANDUSKY.

The Ohio Soldiers' and Sailors' Home is in Erie County about three miles south of the city of Sandusky. The Home has an average total population of about 1,125 persons. A water supply was installed about the year 1886, when

arrangements were made to purchase water from the city of Sandusky. According to the officials of the institution, the daily consumption is about 125,000 gallons. A small inadequate system of sanitary sewers was in existence in the earlier history of the Home, and the present enlarged system dates from the year 1903. The present system of sanitary sewers comprises about ¾ of a mile of pipe sewers which range in size from 6 to 12 inches. Although on the separate plan, the roofs of a number of the buildings are connected with the system for flushing purposes, and hence the flow of sewage is largely increased during storms. The sanitary sewage is conducted through several hundred feet of a main 12-inch sewer to a sewage purification plant.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In March 1902, complaint was entered with the State Board of Health regarding an alleged nuisance said to be due to the improper disposal of sewage from the Home. The secretary of the Board investigated conditions and found that sometime since, by private subscription, the citizens of Sandusky had constructed a sanitary sewer for conveying part of the sewage of the Home into an arm of Sandusky Bay which terminates in swamp land. Owing to the lowering of the lake level marked pollution was effected and offensive odors emanated from the swamp land and ditches. The outcome of this report, after a conference with the officials of the Home, was an appeal to the legislature for funds for the disposal of the sewage of the institution in a satisfactory manner. Subsequently, the seventy-fifth General Assembly appropriated $23,000 for the construction of a sewage purification plant, a new trunk sewer, and for making alterations in the old sewerage system. Plans for the purification of the sewage of the Home were then prepared and were presented to the Board in April 1902. These plans, which were approved as presented, provided for the treatment of the sewage on intermittent sand filters preceded by septic tanks. The design also included an automatic dosing apparatus.

EXAMINATIONS AND INSPECTIONS.

This plant was examined in detail on June 4-6, 1906, and May 7-9, 1907. Visits of inspection were made in 1906 on March 30 and December 6, and in 1907 on February 14 and October 24.

DESCRIPTION OF PLANT.

The plant is located on a 3-acre tract of land about ½ mile north of the main buildings of the Home. The nearest house is about 300 feet distant. The filters lie on each side of the county ditch, an arrangement which is necessary in view of the peculiar features of the local topography. (See Plate XLV.)

SCREENS.

The crude sewage flows into a small brick screen chamber 3 feet 2 inches square and 3 feet 10 inches deep. The walls and bottom are 8½ inches thick. The main sewer enters and leaves this chamber, respectively, with its invert flush with the bottom. The sewage is screened at this point by a screen 2′-6″ x 2′-10″ in plan, composed of ½-inch iron rods set in an iron frame or header constructed of 2-inch iron strips ½-inch thick. The screen has a clear opening of ½-inch and is inclined about 20 degrees to the vertical.

Septic Tanks.

From the screen chamber, which roughly serves to intercept any heavy mineral matters, the sewage flows into the septic tanks. These are underground tanks constructed of brick and are covered with a groined arch roof supported by brick piers. The top of the roof is covered with an earth fill. The roof is 8½ inches thick and there is a head room of 2 feet 6 inches from the normal flow line to the crown of the arch. Three 3-foot manholes are provided in each tank, and by this means the tank is accessible by a ladder. A manhole is also provided over the sluice gate chamber.

The tanks are each 26′ x 40′ in plan and are 9′-6″ deep to the crown of the arched roof and 7 feet deep to the flow line. The capacity of each tank is 54,500 gallons. The tanks are entirely in excavation. The side walls are 12 inches thick and the dividing wall between the two tanks is 24 inches thick. In each tank there are two piers, each of which has a square section of 12 inches. The piers are 12 feet apart, 8 feet from the ends of the tank and 12 feet from the sides. The bottom of the tanks is of brick 8½ inches thick.

Inlets and Outlets. The sewage enters the tanks from the 10-inch main carrier through a brick chamber 3′ x 4′ in plan and 4′ deep. This chamber is constructed of brick and the walls and bottom are 8½ inches thick. It contains a 10-inch sluice gate which controls the flow to the tank. A similar compartment is provided for the second tank. From this chamber a 6-inch pipe extends downward and enters the tank at a point 3 feet below the flow line. The pipe is extended on both sides of the center line and is caused to enter the tank at two additional points. The three inlets for each tank are 6 feet apart and about 6 feet from the side walls.

The sewage flows from each tank through twelve 2-inch cast iron pipes which have a total area of 0.26 square foot. These pipes are spaced 2 feet c. to c. and are each 2 feet long. Through them the sewage flows into a 6-inch iron pipe which leads upward at the center line of each tank into a brick outlet chamber 3 feet square in plan and 4 feet deep. This chamber is capped with one course of brick and its sides and bottom are constructed of the same material and are 8½ inches thick.

Baffles. No baffles are provided in the septic tanks. The inlets and outlets, however, are trapped, as above indicated.

Sludge Drains. To drain the tanks, the floors of which are practically level, there is provided at one corner at the outlet end of each tank a 12-inch sluice gate which discharges through a sewer to the creek.

Method of Control. The 10-inch gate valves, one for each tank and located at the inlet end, comprise the only control of the rate of flow through the tanks.

By-pass. Leading from the second gate chamber at the inlet of the second tank, there is an 8-inch pipe whereby the sewage may be caused to flow directly into the county ditch. As just described, it is also possible to discharge septic sewage through the sludge drains.

Aerating Channel. In the original design, the sewage from the septic tank flowed on to an aerating device which consisted at first of a basin containing coarse broken stone. Such serious clogging ensued with this arrangement that it was replaced with a series of perforated troughs. In the spring of 1907 this device was abandoned and in its place there was constructed a concrete channel 6 inches deep and 12 in. wide, containing on the bottom a series of depressions 3 inches deep and about 3 feet apart. This channel conveys the sewage from each outlet to a common channel which terminates in the dosing chamber. The channel is approximately 40 feet long and is laid on a grade of about 2.5 per cent.

Measuring Weirs. No special arangements are provided for measuring the

sewage flow, which may be roughly obtained by noting the operation of the dosing tank.

FILTERS.

The sewage after treatment in the septic tanks receives a final purification on eight intermittent sand filters. These filters are each ⅛ acre in area and are practically in the form of isosceles triangular with two sides 100 feet long and one 80 feet long. The separate units are divided by earth embankments and the county ditch divides the filters into two parts which contain four units each.

Filtering Material. The filtering material is an excellent grade of lake sand which was hauled by wagons from a point on the lake shore about three miles distant. The sand has an effective size of 0.28 m. m. and a uniformity coefficient of 1.6. The depth of sand is 4 feet 3 inches.

Underdrains. The filters are underdrained by a main drain of 6-inch vitrified sewer pipe laid with open joints. Four-inch lateral drains of similar material and construction are branched from the main drain. The underdrains are laid in depressions and over them is placed a 6-inch layer of gravel. Over the entire bottom of the filters there is also a layer of coarse gravel 6 inches deep. The total original depth of filtering material was about 4 feet 9 inches. No means for ventilating the underdrains are provided.

Dosing Devices. The filters are flooded by an automatic dosing machine, which is contained in an ornamental brick and stone building. The dosing tank proper is 12′ x 30′ in plan and 3′-6″ deep, and has a capacity of about 9,500 gallons. The tank is built entirely of concrete.

The application of the dose is effected by a 12-inch siphon, which has a depth of draw of 36 inches corresponding to about 7,500 gallons. The discharge from the siphon is automatically diverted to the four filters in service in turn by a patented device which consists of an iron cylinder with four ports or openings which lead to the respective discharge pipes. Inside this fixed cylinder is a movable cylinder which contains one port only, and through this port the sewage is passed to the filters in turn. A change in the position of the open port, namely, ¼ of a circle, is accomplished by the rise and fall of a float which engages a rack and pinion. The center rod of the float is provided with as many pawls as there are openings in the discharge chamber, and when the float rises these pawls cause a ¼ revolution of the inner cylinder; the shaft moves freely on the downward movement of the float. By changing the position of the inner cylinder, the second set of four filters may be placed in service.

Distribution Devices. Sewage from the dosing tank flows through four lines of 12-inch vitrified sewer pipe which are embedded in concrete. They are carried across the county ditch on a concrete arched bridge. The distribution on the filters themselves is effected by a wooden carrier 8 inches deep. The central carrier has a cross-sectional area of 48 square inches. At the change of section, wooden slabs are provided, two of which have an area of 8 square feet, one 12 square feet, and one 10 square feet. The distributors are branched so that the distribution will be uniform over the entire area of each filter.

Effluent Discharge. The effluent from the filters flows by gravity through short lengths of 12-inch pipe. One outlet is provided for each set of four filters. While local conditions are such that there is no liability of floods, yet very high flows in the sewers which occur during storms necessitate the by-passing of the plant to the county ditch.

SEWAGE FLOW.

From July, 1906, to September, 1907, careful daily records have been kept of the number of discharges of the dosing tank. The tank has a discharging

capacity, allowing for inflow, of 10,000 gallons. These records show that the average rate of flow in the drier months is about 170,000 gallons in 24 hours. The maximum rate of flow during the above period was 350,000 gallons and the minimum 160,000 gallons, or 16 discharges of the dosing tank in 24 hours. The records which are tabulated below, together with the temperatures of the air and the crude sewage, indicate the general effect of wet weather. The average flow corresponds to 151 gallons per person tributary and is considerably greater than the water consumption, due no doubt, to the entrance of ground water.

TABLE NO. 94.

Average Temperature of Air and Sewage and Monthly Average Sewage Flow.

Month. 1906-07.	Temp. Deg. F.		Sewage Flow. Gallons in 24 Hours.		
	Air.	Sewage.	Average.	Maximum.	Minimum.
July, 1906	75	77	180,000	250,000	160,000
August	77	78	180,000	250,000	160,000
September	67	72	173,000	250,000	160,000
October	53	67	173,000	200,000	160,000
November	40	61	170,000	300,000	160,000
December	33	59	188,000	250,000	160,000
January, 1907	28	53	174,000	350,000	160,000
February	24	52	168,000	200,000	160,000
March	41	62	182,000	350,000	160,000
April	40	64	170,000	200,000	160,000
May	50	65	176,000	250,000	160,000
June	65	72	184,000	300,000	160,000
July	71	74	170,000	350,000	160,000
August	71	76	170,000	250,000	160,000
September	64	73	170,000	250,000	160,000

COMPOSITION OF CRUDE SEWAGE.

Analyses of the crude sewage were made on the two detailed examinations, covering the full period of 24 hours and the samples were averaged to represent the day and night flows. Detailed analyses are presented beyond. The sewage is typical of that of institutions as it contains considerable rags, paper and at times large quantities of soapy material from the laundry. The sewage is practically free from dissolved oxygen and nitrogen as nitrates and nitrites. The average temperature is high but is normal for institutions.

As the data in the above table show the temperature of the sewage in the coldest month of the winter of 1906 and 1907 averaged 52 degrees F.

OPERATION.

The chief engineer of the Home has general charge of this plant. The actual operation is under the care of one of the soldiers who devotes his entire time to this work. Occasional assistance has been secured from the labor force at the institution. No pumping is necessary and the operation relates to the super-

vision of the dosing apparatus and to the care of the sand filters. During the special investigation, careful records were kept of the leading features of operation.

Screening.

The screen through which the crude sewage flows from the institution removes considerable coarse material from the sewage, particularly paper and rags which are present in large quantities. Several times daily it is customary to clean the screen with an iron toothed rake. The accumulated screenings are removed at intervals and are buried.

Septic Tanks.

Ordinarily, both septic tanks are in service at one time. Based on the average sewage flow, this practice affords theoretically a 15-hour period of flow, (linear velocity 0.22 m. m. per second) but due to the accumulation of scum and sludge, the actual period is no doubt somewhat less. At rare intervals it is necessary to by-pass the septic tanks on account of the very high sewage flow incidental to wet weather.

Scum and Sludge Formation. The present caretaker undertook his duties about April, 1906. The attendant in charge previous to this date was incompetent and the management of the plant is especially to be criticised. With a view to reducing labor entailed in maintaining the filters in good condition, it was his practice once each week to open the sludge gates at the outlet ends of the tanks and to allow a part of the lighter sludge to flow into the county ditch. (See report of State Board of Health, 1905, p. 135.) During this investigation, however, this practice has ceased and in fact since the plant was first operated, five years since, other than the above, no sludge nor scum have been removed from the tanks. The quantity of scum and sludge in the septic tanks has varied somewhat from time to time, but during this investigation it was noticed that the greater part of the deposit is present as scum. On the visit of May 7, 1907, the scum in tank No. 1 averaged 2 feet 6 inches in thickness, and was incrusted on the top. In the second tank, the scum on the south side showed a depth of 2 feet 6 inches, but on the north side of the inlet it was 4 feet in thickness and rose about 3 feet above the flow line of the tank. The scum was very hard and appeared to be well oxidized on the surface. Presumably the removal of scum will be necessary in the future, although the actual cross section of the tank is not decreased so much as would be true if the total volume of the accumulation were in the form of sludge. It was noted also that the scum was infested with a heavy growth of insect larvae. So far as could be learned the deposit of actual sludge is generally very small.

Clogging of the Inlet Valves. Considerable difficulty is experienced with the inlet valves, the seats of which are frequently clogged with rags, paper and matches, especially since the inlet is so designed that it is difficult to remove obstructions. Furthermore, in order to equalize as much as possible the flow of sewage through the two tanks it is necessary to throttle the valve controlling the inlet to the first tank so that this inlet is subject to more frequent clogging and hence the second tank receives the greater volume of sewage, a fact which probably in part accounts for the greater accumulation of scum in this tank.

Dosing Apparatus.

As ordinarily operated, one-half of the plant, or four filters are flooded in rotation for a period of one week. The setting of the dosing apparatus is then changed. The operation of the device was very satisfactory on the first examination, the action of the siphon was positive and each of the four filters in service

received its dose in turn. During wet weather the flow of sewage is so high that the dosing siphon cannot be vented, since sewage flows into the dosing chamber practically as fast as it is discharged through the siphon. At times it is, of course, necessary that the apparatus be oiled and that it receive the attention necessary for all kinds of machinery. During this investigation at certain times the apparatus has not been in successful operation. Some difficulty was experienced as to the operation of the regulating air valve and in 1907 a new valve was obtained. On the second examination, the plant was substantially hand operated as it was found that a certain amount of foreign matter had entered the U shaped tube, in which passes the plunger of the float carrying the rack which operates the mechanism for rotating the flow from one filter to the next. In view of this condition, the play of the float was not sufficient to lock the gears. Subsequently, quite extensive repairs were made and on the final inspection the apparatus was in normal operation.

Break in Effluent Channel. On the first detailed examination, it was noticed that there was considerable leakage in one of the four distribution pipes which lead from the dosing tank and hence it was impossible to keep the surface of one of the filters dry while resting. In view of this condition, the State Board of Health advised that the pipes be repaired, a recommendation which was finally carried out in the summer of 1907.

FILTERS.

The entire application of sewage is, of course, performed by the dosing apparatus, as already described. During the reconstruction of the aerator, as noted in May, 1907, for two weeks, only two filters were used. Considerable clogging was the result, and no doubt, a somewhat lower efficiency than the normal. The average rate of flow of 170,000 gallons in 24 hours corresponds to the same rate per acre, or an actual average rate of 340,000 gallons. Based on the population, the sewage of the Home is treated at the rate of 1,125 persons per acre.

In operating the filters, the surfaces are raked and cleaned at frequent intervals and are cultivated with a hand operated wheel harrow about twice each month. To prevent the disturbance of the sand adjacent to the distributors, small stones which have been raked from other portions of the filters have been tamped into the sand at these points. This expedient appears to have served admirably in protecting the sand from undue disturbance adjacent to the distributors and the practice could, no doubt, be followed to advantage in similar plants.

The filters are flat surfaced in the summer time, but are furrowed in the winter season with furrows 8 inches wide and 4 inches deep arranged to lead towards the center of each filter. Ordinarily, sewage passes through the sand very rapidly even in the winter time and no difficulties have been experienced in cold weather, except that the sand at the opening of spring is generally considerably clogged, as under winter conditions the filters cannot be cleaned so frequently as is essential under conditions at this plant. On one visit it was noted that the discharge of the dosing tank lasted 12 minutes and that the effluent first appeared in the underdrains 19 minutes after the sewage was first applied to the surface of the sand.

Continual cleaning, raking and scraping since the plant was installed gradually reduced the thickness of the sand, so that as was noted on the first visit and the first detailed examination, low points were visible in all of the filters. The State Board of Health subsequently advised that the filters be leveled and be resanded. The officials of the Home acted on this suggestion and from September 6 to November 22, 1906, sand was hauled to the plant and a number of men were engaged in resanding the filters. The dirty surface sand was entirely removed to the estimated extent of 90 cubic yards. To replace this sand 52 two-horse loads of sand were hauled to the plant from the lake at a cost of $1.25 per cubic yard. The sand

was not all used at one time and a sufficient quantity was on hand so that the filters could be resanded from time to time as occasion required. In the case of one of the filters, 24 cubic yards of clean sand were placed in August, 1907. On the final inspection all of the filters had been resanded and were found to be level and in excellent condition.

On the visit in May, 1907, it was noted that the wooden distributors were greatly in need of repair. They had been in use for five years.

EFFICIENCY.

Analytical data, observations made at visits and inspections of the county ditch afford evidence of the general efficiency of the plant, in regard to its several parts and as to the broader problem of the purification of sewage of the Home.

Septic Tanks.

The roughly screened sewage of the institution after treatment in the septic tanks appears to be little changed, with respect to suspended matter, according to evidence obtained during this investigation. The results of the analyses of 24-hour average samples collected on the two detailed examinations show average suspended matter of 87 and 91 parts per million, respectively. The removals of suspended matter based on the weighted analyses of the crude sewage for corresponding periods were only 7 and 2 per cent., respectively. The low efficiency of the tanks in the removal of suspended matters appears to be due to the accumulation of scum and suggests that the tanks should be cleaned. Moreover, on all visits small particles of black suspended matter have been noted in the effluent, but it appears that even though the septic effluent carries as high as 90 parts per million of suspended matter, yet the operation of the sand filters has not been greatly inconvenienced. Dissolved oxygen is not found in the effluent from the septic tanks and on each of the examinations none was present in this strong institutional sewage except during the night.

Aerator.

The removal of the aerator was advised by the State Board of Health because it was strongly apparent that the feature of aeration was the cause of odors which at times have been noticed at some distance from the plant. In fact, nuisances ascribed to the operation of the plant, due to alleged odors, are probably in a large part attributable to the aerator, which has been one of the chief points of criticism of the plant from the standpoint of odors. Pursuant to the advice of the Board in April, 1906, the aerator was removed and in its place was constructed a series of concrete channels, already described. It is probable that the aerator did not exert a material effect upon the resulting purification, in fact the aeration of the septic sewage in cold weather caused a decided loss in temperature. On the visit of Feb. 14, 1907, the temperature of the air in degrees F. was 28, that of the crude sewage 67, and that of the applied sewage 50, a loss by aeration of 17 degrees. No data are available as to the efficiency of the aeration afforded by the old aerator, but on the second examination dissolved oxygen samples of the septic sewage before and after aeration were taken at 4-hour intervals for a period of 24 hours. No dissolved oxygen was found in any of the samples. The crude sewage for the same period contained from 0.0 to 1.4 parts per million of dissolved oxygen. Since the new aerator has been used there has been little odor about the septic tanks.

Filters.

All analyses of samples of the effluent from the filters, collected during this investigation, have shown a very high purification and the nitrification produced

is higher than at any other similar plant in the state. The effluent is always odorless, generally of low turbidity, and contains but little organic matter. The large quantity of nitrogen as nitrates, no doubt, tends to improve materially the waters of the county ditch.

SUMMARY.

Prior to this investigation, the plant was very poorly managed and at times was practically neglected. The discharge of sludge from the septic tanks, then practiced, gave rise to numerous complaints which were finally formally lodged with the officials of the Home, and it was contended that the waters of the county ditch were receiving considerable pollution from the sewage of the Home. An inspection of the brook for a distance of about one-half a mile below the plant showed numerous deposits of foul-smelling sludge which, no doubt, originated from the previous practice of discharging sludge from the septic tanks at weekly intervals. Since at that time the plant was receiving excellent supervision and was producing a well-purified effluent, the condition of the brook and any possible odors arising therefrom were thought to be chiefly attributable to past mismanagement.

The septic tanks have not been especially efficient in removing suspended matter from the crude sewage, but the application of the septic effluent to the sand filters has not caused serious clogging, although constant care has been necessary in order to keep the filters in serviceable condition. Ordinarily, the automatic apparatus has been very satisfactory, but occasional interruptions in its operation have resulted in marked inconveniences in the operation of the filters, a fact which illustrates the important relation between the proper action of the dosing apparatus and the successful operation of the plant. Since April, 1906, this sewage purification plant has been most carefully and faithfully operated and its generally well-kept appearance is especially to be commended. Conditions have been considerably improved during this investigation by the removal of the aerator, the repairing of the leaky distribution pipes and by the resanding of the filters. On the final inspection during this investigation the efficiency of the plant continued to be high and the purification effected was such that the sewage of the Home was being disposed of in a very satisfactory manner.

COSTS.

Exclusive of engineering, the first cost of the plant was $12,800. The filters cost $7,560 per acre.

TABLE NO. 95.

Cost of Construction.

Land	$2,000
Filters	7,560
Tank and Dosing Chamber	3,240
Total	$12,800

Operating expenses during the years 1905, 1906 and 1907, have been, respectively, $144, $291, and $903. This is on a respective per capita basis of 13, 26 and 80 cents. The ordinary cost of operation is the salary of the caretaker at $15 per month. In 1906 the cost of resanding the filters was $120. The high cost for the year 1907 was due to unusual expenses for repairs. Repairs to the dosing machinery cost $198.95; the reconstruction of the aerator and repairs to the piping from the dosing tank cost $481.67; all incurred in 1907.

TABLE NO. 96.

Results of Chemical Analyses.

Date 1906-07.	Hour of Collection.	Temp. Deg. F.	Parts per Million.														
			Oxygen Consumed.		Nitrogen As					Chlorine.	Suspend'd Matter.		Free Carbonic Acid.	Dissolved Oxygen.	Putrescibility.	Fats.
					Organic		Free Ammonia.	Nitrites.	Nitrates.							
			Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.				
Crude Sewage.																
June 5, 1906.....	5:30 A.- 8:30 P.	72	48	33	6.6	3.6	15.0	0.00	0.0	51	110	75	34	0.0	....	70
June 5-6, 1906....	9:00 P.- 5:00 A.	72	51	29	9.3	3.7	12.5	0.08	0.0	37	81	51	18	0.0	....	41
Weighted Av'ge.		72	49	31	8.0	3.7	13.8	0.04	0.0	44	96	63	26	0.0	....	56
May 8, 1907*.....	5:00 A.- 8:30 P.	....	.....	.....	8.0	7.0	12.0	0.10	0.0	42	142	94	52	0.9	....	43
May 8-9, 1907....	9:00 P.- 4:30 A.	....	.....	.....	6.0	6.0	10.0	0.06	0.0	23	44	19	35	.....	....	8
Weighted Av'ge.		....	.....	.....	7.0	6.5	11.0	0.08	0.0	33	93	57	44	0.6	....	26
Septic Sewage.																
June 5-6, 1906....	8:30 P.- 1:00 P.	73	34	26.3	5.7	1.7	22.5	0.00	0.0	46	87	54	36	.....	....	.....
May 8-9, 1907....	9:30 A.- 8:30 A.	....	.....	.....	12.0	.....	12.0	0.00	.....	189	91	.....	.....	0.0	....	.....

Effluents.

June 5-6, 1906....	4.30 P.	No. 2...	68	8.4	.....	1.6	.....	0.4	0.02	28.0	.....	8	.....	.....		0	.....
June 5-6, 1906....	to	No. 4...	68	7.4	.....	1.4	.....	0.2	0.01	30.0	.....	6	.....	.....		0	.....
June 5-6, 1906....		No. 6...	68	9.2	.....	0.5	.....	0.7	0.09	31.0	.....	20	.....	.....	4.2	0	.....
June 5-6, 1906....	11:35 A.	No. 8...	68	8.4	.....	0.6	.....	0.6	0.08	30.0	.....	21	.....	.....		0	.....
Average			68	8.3	.....	1.0	.....	0.5	0.05	30.0	.....	13	.....	.....	4.2	0	.....
May 8-9, 1907....	9:00 A.-	8:30 A.	....	.....	.....	.....	.....	2.8	0.04	32.5	.....	28	16	.....	4.0	0	.....

TRUMBULL COUNTY INFIRMARY, WARREN.

The infirmary of Trumbull County is about three miles east of the city of Warren and is on the west bank of Young's Run, a small tributary of the Mahoning River. In the early history of the institution there were no modern sanitary conveniences, although about the year 1894 some sanitary sewers had been constructed. Four years later a sewage purification plant was built and at that time additions were made to the sanitary sewers which now comprise about 685 feet of 6-inch and 8-inch vitrified pipe. This system serves a population estimated at 90.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

In 1899, the sewage from the institution flowed directly into Young's Run and although the women's building was equipped with a Smead system of dry closets and the water closets in the men's quarters were used only as slop sinks, yet the direct discharge of the sewage of the infirmary caused the board of health of Warren to bring suit against the county commissioners for the removal of this source of pollution of the city's water supply.

As a result of this suit, the county commissioners employed sanitary engineers to prepare plans for the purification of the sewage of the institution. Plans were completed late in 1898 and were subsequently submitted to the State Board of Health for approval. In general terms, the proposed plant comprised a septic tank, a storage reservoir or pump well, pumping machinery and two filters constructed of fine coke breeze. The Board approved these plans in March, 1899, on condition that no overflow should be provided whereby through neglect to pump the sewage, the excess would flow into the run without treatment.

EXAMINATIONS AND INSPECTIONS.

During this investigation, visits of inspection were made on May 23, 1906, and in 1907, on Jan. 10 and Oct. 30.

DESCRIPTION OF PLANT.

The purification of the sewage of the institution is carried out on a 10-acre plot located about 600 feet from the main building. The septic tank, reservoir and pump house are situated on Young's Run adjacent to the main buildings of the institution. (See Plate XLVI.)

Septic Tank.

The crude sewage from the institution is not screened, but flows directly into a septic tank of brick 5 feet 6 inches x 15 feet in plan and 6 feet to 6 feet 9 inches deep. The side walls are 12 inches thick and the end walls are 8 inches thick. The bottom is of concrete 6 inches thick. The average depth to the flow line is 5 feet 4 inches and the average capacity is 3,300 gallons. The tank is not baffled. It is covered with a brick roof 4 inches thick and arched with a 6-inch rise. There is a clear opening of 18 inches to the crown of the arch. Two small openings with wooden covers are provided in the roof of the tank. These covers are made air tight but are so arranged as to be readily forced in case of excessive gas formation.

Inlets and Outlets. The 9-inch main sewer enters at the top of the tank, flows through a 90° elbow turned downward and terminating at a point 2 feet

Trumbull County Infirmary, Warren. View Showing Pump House (Small Building in Center) and Main Infirmary Buildings.

Trumbull County Infirmary, Warren. — General View of Filters.

6 inches below the flow line. In leaving the tank, the sewage flows from the end opposite the inlet over a weir 3 feet long and falls on to three steps for the purpose of aeration. The outlet is trapped by a sheet iron partition which extends from the roof to 2 feet 6 inches below the high water mark. This partition is supported by brackets built on the brick wall and bolted through the middle wall.

Sludge Drain. The floor of the septic tank slopes 8 inches in 15 feet or about 1 to 24 to a 12-inch sluice gate located at the outlet end of the septic tank. By opening this gate it is possible to cause the contents of the septic tank to flow into the reservoir adjoining.

Method of Control. No special means are provided for controlling the flow through the tank, and the period of retention depends upon the rate at which sewage flows from the institution.

By-pass. A 12-inch overflow controlled by a flap valve and located at the outlet end of the septic tank permits the discharge of sewage into Young's Run in case the capacity of the tank and the reservoir is exceeded. The overflow discharges into a 9-inch sewer which is provided at its lower end with a second flap valve to prevent back flooding from the stream during high water.

Aerating Channel and Measuring Weirs. To provide for aeration, the septic sewage is caused to flow over three steps 3 feet wide located adjacent to the septic tank. No facilities are provided for measuring the sewage flow.

Reservoir or Pump Well.

Sewage from the septic tank falls into a reservoir or pump well of brick 5'-6" x 15' in plan and 7' to 7'-8" deep, with an average depth to the flow line of 6 feet 8 inches. The tank has a capacity of 4,000 gallons. The floor slopes 1-24. At the inlet end in which is located the suction of the pump, there is a sump 2 feet below the normal floor line. The reservoir is constructed substantially as is the septic tank, both of which are enclosed with a brick arched roof. Additional features of interest relating especially to the reservoir refer to an air inlet adjacent to the outlet of the septic tank to assist in the aeration of the septic sewage. The other end of this vent pipe is carried to the chimney over the boiler house. Directly over the reservoir there is a wooden pump house about 10 feet square. Reinforcing the brick reservoir are four lines of ¾-inch tie rods anchored with 5x5-inch steel angles.

Sludge Disposal Area.

No facilities are provided for disposing of sludge.

Pumping Plant.

The sewage from the reservoir is pumped through a 3-inch wrought iron pipe 520 feet long. This force main is laid on a continuous rising grade so as to prevent dribbling at the point of discharge on to the filters. The pump is a duplex steam pump 4.5x1.5x5 inches and is operated by steam from the boiler house. Dependent upon the level of the sewage in the reservoir, the ordinary lift is from 12 to 16 feet.

Filters.

The purification of the sewage settled in the septic tank and reservoir is carried out on two intermittent filters of fine grain material. They are each 30 feet square, or 0.02 acre in area, with a total area of 1,800 square feet or 0.04 acre. The two filters are surrounded by earth embankments and are separated by a similar fill.

Filtering Material. The filters are 4 feet 6 inches deep and are constructed of fine coke breeze which ranges in size from 1/16 to ¼ in. The material was shipped on cars to a siding about one-fourth of a mile distant, whence it was hauled to the plant in wagons.

Underdrains. The filters are underdrained with a single line of 4-inch vitrified sewer tile located in the center of both filters. No lantern holes nor other means of ventilation are provided. Directly over the underdrains is a layer of coarse crushed coke with a maximum thickness of 6 inches. This layer is diminished to zero thickness at the sides of the filters and there is thus formed a level surface, on which rests the main body of the filtering material. To effect this, the excavation for the filter was sloped 1 to 30 corners to center.

Dosing Devices. Sewage is applied to the filters by pumping through the wrought iron force main already described. At the center of the embankment supporting the filters the pipe enters a loosely fitting elbow which is provided with a 3-foot nipple and thus permits a discharge on to either filter.

Distribution Devices. Sewage from the force main falls on to a concrete slab 4 feet wide and 3 inches thick which extends across each filter directly over the underdrains. No other means of distribution are provided.

Effluent Discharge. The effluent from the filters flows by gravity through about 20 feet of 4-inch vitrified pipe into a ditch leading into Young's Run. To protect the filters from high water in Young's Run, a dyke surrounds the plant at a proper elevation.

SEWAGE FLOW AND COMPOSITION OF CRUDE SEWAGE.

In dry weather, the septic tank is said to be filled once daily and the corresponding flow of sewage is about 3,300 gallons or 37 gallons per person tributary. No more detailed information is available as to the sewage flow, but it is said that in wet weather the volume of flow is at times at least twice the above quantity.

No analyses of composite average samples of the crude sewage were made during this investigation. The analysis of samples collected in 1903, however, indicates that there are no unusual features in relation to the character of the crude sewage, which is normally of moderate strength, but during wet weather is greatly diluted with rain water. (See analysis of chance sample collected on August 11, 1906.)

OPERATION.

The sewage purification plant of the institution is under the supervision of the superintendent and its operation is in direct charge of the stationary engineer of the infirmary. Sewage is pumped from the reservoir to the filters once daily in dry weather for from three-quarters to one hour. In wet weather, it is necessary to operate the pumps twice each day. The septic tank and reservoir requires practically no attention. The septic tank has been cleaned only once since it was built, some eight years ago. There is very little sludge accumulation and practically no scum. During wet weather, the reservoir at times fills completely and the sewage backs back through the septic tank, thence to the manhole on the main sewer. At times it is stated that odors arise from the pump house, especially during the later part of the pumping period, but no objectionable odors were noted on any of the visits made during this investigation. The period of flow in the septic tank is 24 hours and the corresponding linear velocity is 0.05 m. m. per second.

Some difficulty has been experienced in operating the pump as the packing of the valves is at times attacked by the gases which arise from the sewage.

One filter receives the sewage daily and the two units are in use on alternate days. The dose of sewage is about 3,300 gallons and the actual rate of filtration is 165,000 gallons per acre per day. The average rate is one-half this figure and corresponds to a rate of 2,200 persons per acre. Vegetation tends to grow on the filters and its removal is necessary from time to time. In the fall of 1906, it was thought that the sewage passed to the underdrains too rapidly and the filters were spaded 6 inches deep and were then rolled with a 250-pound roller in order to compact the surface. During the eight years' operation, while the upper 6 inches of the filtering material has somewhat compacted, the main body of the coke appears to be in excellent condition and is not disintegrated.

EFFICIENCY.

The few available analyses of the effluent from the filters indicate that the sewage of the institution is well purified at all times. Even in cold weather, the sewage disappears rapidly from the surface of the filters and as noted on the inspection of Jan. 10, 1907, the effluent appears in the underdrains in from 10 to 12 minutes after the dose of sewage is first applied. The analyses indicate that the effluent is well nitrified and low in organic and suspended matters. There is practically no odor from the plant, although during flooding some odor arises from the surface of the filters, and is noticeable perhaps 100 feet distant.

The plant receives excellent supervision and is well operated. The purification of the sewage of the institution is carried out without offensive odor and since the plant has been in service, no complaints have been entered as to the organic pollution of Young's Run.

COSTS.

Available cost data as to the construction of the plant are only the engineer's estimates, these figures do not include the item of labor which was largely performed by the inmates of the institution.

TABLE NO. 97.

Estimated Cost of Construction.

Sewers	$ 52
Reservoir, septic tank, pumping and piping	512
Force main	87
Filters	410
Ten per cent contingencies	106
Total	$1,167

The operating expenses are practically nothing. The expense of maintaining the institution is not increased by virtue of the operation of the sewage purification plant. Ordinarily, the operating expenses would be the value of the steam used in pumping and the labor of one man about one hour daily.

TABLE NO. 98.

Results of Chemical Analyses.

Date 1906	Hour of Collection.	Parts per Million.												
		Oxygen Consumed.		Nitrogen As					Chlorine.	Suspnd'd Matter.		Putrescibility.	Fats.
				Organic.		Free Ammonia.	Nitrites.	Nitrates.					
		Total.	Dissolved.	Total.	Dissolved.					Total.	Volatile.		
						Crude Sewage.							
Aug. 11, 1906.....	11:00 A. M.....	24	20	6.5	4.1	4.5	0.07	4.0	9.5	32	20	+	13
						Effluent.							
Aug. 11, 1906.....	11.00 A. M.....	8	.....	0.7	.....	0.2	0.06	10.0	7.8	<5	0	0	.....

WARRENSVILLE, CLEVELAND TUBERCULOSIS FARM COLONY.

The city of Cleveland maintains a Tuberculosis Hospital at the city's Farm Colony near Warrensville, Ohio. The farm is some ten miles southeast of the city and is on a tract of land at an elevation somewhat higher than that of the city itself. Plans for the hospital were prepared in the latter part of 1905, and in November, 1905, application was made to the State Board of Health for the approval of plans for the purification of the sewage of the Colony. The purification of the sewage was distinctly desirable since there is no water course of sufficient flow into which the sewage could be discharged for disposal by dilution, and further in view of the infectious character of the sewage which presumably would require some form of disinfection before its discharge into a water course.

The plans for the purification of the sewage of the Colony, were approved by the Board in November, 1905, provided that the size of the plant should be increased when deemed necessary and that the method of operation should be at all times satisfactory. The plans as submitted provided for the sewerage of about 125 persons. The present population is, however, only about 100. It was estimated that the daily flow would be in the vicinity of 6,000 gallons. In general terms, the treatment proposed was screening, sedimentation in a septic tank, and final filtration on intermittent sand filters dosed by a siphon.

INSPECTIONS.

During this investigation a preliminary inspection was made on June 24, 1906, and was followed by a second inspection on February 12, 1907.

DESCRIPTION OF PLANT.

The purification of the sewage of the hospital is carried out on a 2-acre tract of land about 600 feet from the administration building. The sewage is conducted by gravity through 600 feet of 6-inch sewer pipe.

Screen Chamber.

The crude sewage is first screened through ½-inch iron bars inclined 30 degrees to the vertical and set with a clear opening of ¾ inch. The screen is contained in a small concrete chamber 2x4 feet in plan and 2 feet 9 inches deep.

Septic Tank.

From the screen chamber the sewage flows into an uncovered septic tank 7'x9' in plan and 5 feet deep to the flow line. The tank has a capacity of about 2,300 gallons. It is constructed entirely of concrete with walls 13 inches thick and provided with an inner lining of one course of shale brick. The bottom is of 6-inch concrete.

Inlets and Outlets. The sewage flows into the tank through one 6-inch elbow which is turned downward and extends 2 feet 6 inches below the flow line. The outlet is similarly constructed.

Baffle. One transverse vertical baffle is provided 2 feet from the inlet end and is submerged to a depth of 2 feet 10 inches.

Sludge Drains. No sludge drains are provided and the floor of the tank is level.

Measuring Weirs and Aerating Channel. Facilities for measuring the sewage are not provided nor are there any arrangements for aerating the sewage after sedimentation.

By-pass. From the side of the screen chamber through the sludge filter there is a 6-inch pipe which allows the discharge of crude sewage directly to the brook.

Sludge Disposal Area.

To provide for cleaning the septic tank, there is a sludge filter 9x12 feet in plan and 5 feet deep. This filter is contained in a concrete tank constructed of 13-inch walls, which are plastered with 1 inch Portland cement mortar. It was proposed to fill this tank with sand for use as a filter. At the end of 1906 this filter had not been in service. In cleaning the septic tank it would be necessary to pump sludge from the septic tank on to the disposal area.

Dosing Tank.

Sewage from the septic tank flows directly into a dosing tank of concrete similar in construction to the septic tank. This tank is 8 feet square and 2 feet 6 inches deep and has a capacity to the flow line of about 960 gallons. It is discharged through a short length of 6-inch pipe by a single 5-inch siphon which draws 2 feet.

Filters.

The final purification of the sewage is carried out on intermittent sand filters. These are four in number and each has a superficial area of 30 x 36 feet and a bottom area of 24 x 30 feet. The total effective area is 0.085 acre. The filters are constructed of sand obtained from an adjacent bank and are surrounded and separated by embankments formed from the excavation necessary during construction. These embankments are not seeded.

Filtering Material. The filtering material is a medium grade of bank sand 3 feet deep and on inspection appeared to be suitable for sand filtration.

Underdrains. The underdrains comprise three lines of 4-inch tile which lead to two 6-inch main drains. The lateral lines are 12 feet 6 inches apart. No ventilation is provided for and no coarse material is placed directly over the drains.

Distribution Devices. Sewage from the dosing tank flows on to a main wooden carrier. This distributor is 8 inches wide and 6 inches deep and when branched is 6 inches wide. It is provided with wooden shear gates for diverting the sewage to the several units.

Effluent Discharge. The effluent from the filters flows by gravity through about 80 feet of 6-inch pipe which leads to a small brook which serves to drain the farm.

OPERATION AND EFFICIENCY.

On the first visit the plant had been in service only a short time, and at this time general information was obtained relative to its construction. The results of the inspection of February 12, 1907, however, furnished some information as to its operation and efficiency. The day of this visit was clear and cold with an air temperature at mid-day of 12 degrees F. The plant was practically out of service and it was stated that no sewage had been applied to the sand filters since December. It was learned that at the first freeze, it was not thought to be practical to operate the sand filters properly, owing presumably to the small volume of sewage and the long period between successive doses. The plant had been in service for several months, but it appeared from the condition of the

sand that the filters had received very little sewage and that the plant in general had not received the supervision necessary to enable the hand operating features to afford successful operation. The sewage flow was in the vicinity of 6,000 gallons which corresponds to a per capita flow of 60 gallons and were the filters in service, the average rate of operation would have been about 70,000 gallons per acre per day, corresponding to 1175 persons per acre. Heaps of screening were noted near the screen chamber and presumably had been accumulating for some time. At this visit the crude sewage was being by-passed directly into the brook. Based on the average sewage flow, the period of retention in the septic tank is about 9 hours and the corresponding linear velocity is 0.08 m. m. per second.

The results of this inspection indicate that the plant should receive greater supervision. Its condition pointed strongly to the fact that especially careful supervision is necessary on account of the feature of hand operation, and that unless the sewage is regularly diverted to successive filters, the filters will be over-dosed and will eventually clog to the decided detriment of the final effluent. Under conditions which have prevailed since the plant was first operated, it appears that no nuisance has been experienced, although at certain times some odor is said to have been noted at the administration building, which is only about 600 feet distant. The rate of filtration is moderate and provided the plant receives the necessary supervision, it should provide a safe and satisfactory disposal of the sewage of the colony.

COSTS.

No data are available as to the cost of constructing the plant. Operating expenses are practically nothing.

COLLINWOOD, LAKE SHORE AND MICHIGAN SOUTHERN RAILROAD SHOPS.

The Lake Shore and Michigan Southern Railroad maintains large shops at Collinwood in the thickly built up portion of the village. The shops have an average population of 1,525, this includes a railroad Y. M. C. A. which has an average population in the day time of 20 and in the night time of 80. The shops were constructed about the year 1902 and at that time arrangements were made to obtain water from the city of Collinwood.

SEWERAGE.

A system of sanitary sewers was constructed when the shops were built in 1902. These sewers now comprise about 3,465 feet of vitrified pipe which ranges in size from 6 to 12 inches. There are two trunk sewer lines which terminate at a well whence the sewage is pumped to a purification plant. In addition to these sanitary sewers, there are about 2.1 miles of storm water drains which range in size from 6 to 22 inches. Practically none of the storm water and but few wastes from the shops are admitted into the sanitary sewers.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

When the shops were first constructed, the problem of the proper disposal of the sewage confronted the officials, in view of the fact that the only dilution available is a small stream which leads to Lake Erie, about one-half mile distant. After due consideration of local conditions, it was decided to install a plant for the purification of the sewage. The plant, as constructed in 1902, briefly described, consists of a pump well, two automatically operated pumps, two septic tanks with automatic flushing features and four contact filters, the operation of which is intended to be entirely automatic by virtue of respective filling and discharging siphons. This plant was constructed without the knowledge of the State Board of Health and consequently the plant did not receive the official approval of the Board.

EXAMINATIONS AND INSPECTIONS.

The plant was visited during this investigation on five occasions as follows: In 1906, on April 11, June 18-20, and Dec. 18-19; in 1907. on July 9 and Oct. 17. The second visit was the occasion of a detailed examination and the third was for the purpose of obtaining measurements of the sewage flow. The other visits were for the purpose of general inspection.

DESCRIPTION OF PLANT.

The sewage purification plant of the Lake Shore Railroad shops is located in the northwest corner of the tract of land occupied by the shops. The purification devices are housed so that there is no esthetic objection to its location within so few as 100 feet from the nearest occupied dwelling. (See Plate XLVII.)

Screens.

Two lines of sewers 10-inch and 12-inch, respectively, discharge into a pump well 6 feet in diameter, with a maximum flow line depth of 5 feet and a capacity of about 1,000 gallons. In this well and so arranged that the discharge from the two sewers may receive treatment, is a screen approximately 28 square feet in area, set vertically and constructed of ½-inch bars with a clear opening of 2 inches.

Grit Chamber.

No special arrangements are provided for the interception of heavier mineral matters, as such are, of course, unnecessary for a plant which serves a shop of this character.

Pumping Plant.

The sewage is raised from the pump well by two, 4.5x6x6-inch duplex pumps with bronzed piston rods and brass water pistons. These pumps are driven by compressed air furnished from the main works and are automatically started by a float located in the pump well. The intended rise is 5 feet; as operated, however, the rise of the float is only 4 inches. The sewage is pumped through a line of 4-inch pipe provided with a tee and valves and arranged so that each branch leads to a septic tank. This arrangement allows the use of one or both of the tanks as may be desired. The ordinary lift is about 15 feet, neglecting friction.

Septic Tanks.

The septic tanks are two in number and are constructed of concrete. The walls are 18 inches thick and the bottom 9 inches. The tanks are each 21x10

feet 9 inches in plan and 9 feet deep, with a depth to the flow line of 8 feet and a total capacity of 13,000 gallons each. The septic tanks are completely covered by a concrete roof 9 inches thick and 12 inches above the maximum flow line of the tanks. The roof is supported by 8-inch I beams, placed at 18-foot intervals. Access to the tanks is by a manhole 3 feet square at the inlet end of each tank.

Inlets and Outlets. The sewage raised by the pumps is discharged through a 12-inch perforated pipe which extends across the upper end of each tank, and is located 3 feet 6 inches from the bottom, or 2 feet below the minimum level of the sewage. A 6-inch pipe placed at one corner of each tank allows the flow of sewage into a siphon chamber.

Baffles. No baffles are provided.

Sludge Drain. The floor of each tank slopes one-quarter of an inch per foot towards the inlet. At this inlet end there is an 8-inch valve which permits the discharge of sludge into the pump well.

Method of Control. No special controllers are provided, as the rate of filling depends upon the rate of sewage flow, and the discharge upon the operation of the discharging siphons described below.

By-pass. A valve located in the bottom of the pump well permits the direct flow of sewage to the effluent sewer and thus by-passes the septic tanks.

Aerating Devices and Measuring Weirs. No provisions are made for the aeration of the septic effluent nor for the measurement of the sewage flow.

Effluent Discharge. In distinction from septic tanks, as ordinarily operated, the tanks at this plant have a variable flow line such that the depth of the sewage in the tank ranges from 5 feet 6 inches to 8 feet. This is effected by siphons which intermittently withdraw the sewage from the upper 2 feet 6 inches in the tank. These two alternating siphons are 5 inches in size and are contained in a concrete chamber 4 x 4 feet in plan and 5 feet deep. One set of siphons is provided for each septic tank.

Sludge Disposal Area.

No special provisions were made for the disposal of sludge when the plant was constructed.

Filters.

The filters at this plant are intended to be operated on a fill-and-draw basis and are four in number, each 15x29 feet, or 0.01 acre with a total area of 1740 sq. ft. or 0.04 acre. They are contained in concrete basins about 6 feet deep. The filters are separated by 12-inch concrete walls so that each unit is a separate water tight compartment.

Filtering Material. The filtering material consists of clean broken limestone which ranges in size from ½ to 2 inches and has a depth of 5 feet.

Underdrains. The filters are underdrained with one main drain of 12-inch vitrified sewer pipe. Lateral drains of 6-inch pipe are laid at right angles to the main drain at 6-foot intervals. The entire depth of broken limestone is of the same average size.

Covers. A wooden platform containing trap doors covers the four filters and serves to protect the plant from the weather and renders its location much less objectionable from an esthetic standpoint.

Dosing Devices. As already discussed, the septic tanks are virtually dosing tanks in that the contents of the upper 2½ feet are subject to withdrawal at intervals. For each tank there are provided two siphons which alternate the discharge on to one of the two pairs of contact filters through a short length of 5-inch pipe.

Distribution Devices. From the 5-inch siphons the sewage is distributed on the filters by a main carrier of 8-inch half tile. At about 6-foot intervals, 6-inch lateral half tile extends on each side of the main carrier.

Effluent Discharge. To effect automatically the operation of the contact filters, timed 5-inch siphons are provided, one for each filter. At a point about mid-depth of the filtering material in each filter a 1-inch pipe, controlled by a valve, leads to a time well in which is located the discharging siphon. As soon as this well has been filled to the proper height, the siphon is started.

SEWAGE FLOW.

From the report of the engineer retained to advise as to the purification of the sewage of the shops, it was learned that the plant was designed for a population of about 500. There has been a rapid increase in the population since the shops were built and a corresponding increase in the volume of sewage flow. On this account, on the first two visits to the plant during this investigation it was noted that the automatically started pumps operate with great frequency. This condition indicated a large increase in the sewage flow over and above that of the normal capacity of the plant and it was, therefore, thought desirable to obtain measurements of the actual flow. Accordingly, on Dec. 18-19, 1906, arrangements were made with the railroad officials to have constructed two weirs, one in each of the manholes on the two trunk sewers.

Measurements of the sewage flow were obtained on December 19th, 1906, for a period of 12 hours. The flow was at the rate of 200,000 gallons in 24 hours, or 137 gallons per minute. On the basis of about 1525 persons connected to the sanitary sewers, the per capita flow was about 131 gallons.

COMPOSITION OF CRUDE SEWAGE.

The general arrangement of the storage well and pumping plant renders it difficult to obtain representative samples of the crude sewage at this plant. In view of the general condition of the plant, as will be described presently, no crude sewage samples were collected during this investigation.

The high sewage flow and the fact that the sewage consists essentially of sanitary wastes permits the assumption that the sewage is dilute and ordinarily strictly domestic in character. As indicated by the inspections, considerable oily matters are to be noted in the crude sewage.

OPERATION.

Since the summer of 1906, the operation of the plant has been in charge of the Chemist and Engineer of Tests. Under his direction, daily records have been kept relative to the temperature of the air and of the sewage and general information as to features of operation.

As originally planned, this plant was expected to be entirely automatic, as regard features of operation, excepting possibly the supervision necessary to insure the proper operation of the pumps. It was arranged that when 5 feet of sewage had accumulated in the pump well, the rise of a float would automatically start the pumps which would completely empty the well and raise the sewage into one of the two septic tanks. The septic tanks were intended to serve the double purpose of settling and dosing tanks in that when filled to a certain depth the contents of the upper 30 inches were to be rapidly and automatically removed by a siphon. Two alternating siphons were provided for each septic tank so-

that the contact filters in a given set would be flooded alternately. The length of the contact cycles could be varied at will by virtue of a discharging siphon contained in a time well which would be filled by sewage from the contact filter itself at a rate depending upon the extent to which was opened the shut-off which leads to the time well. According to the setting of the valve on the discharge of the pumps either set of septic tanks and contact filters could be used.

The operation of the plant as originally planned has not been possible throughout the period covered by this investigation primarily because of the largely increased sewage flow. On the first visit to the plant on April 11, 1906, it was noted first that the automatically operated pumps were started and stopped at very frequent intervals as the play of the float in the pump well was only 4 inches, and that the quantity of sewage discharged from a septic tank was greater than the capacity of a contact filter and hence crude sewage eventually flowed into the time well and caused the contact filters to discharge after practically no period of standing full. The period of flow in the septic tanks is only about 30 minutes. It was learned at this visit from the appearance of the filters that the plant had received little attention other than that given to the mechanical details of the pumping plant.

On June 20, 1906, similar operating conditions were noted as in the spring. An inspection of the contact filtering material in the contact filters indicated that the voids to a depth of 30 inches at least were greatly clogged with suspended matters. The railroad officials were advised to clean the filtering material and this was done in August, 1906, when the entire quantity of filtering material was removed and was replaced by fresh stone.

On the visit of December 18, 1906, operating conditions continued to be the same as in the summer. It was learned that when the contact filters were cleaned sludge was removed from the septic tanks. When it was decided to clean the tanks the gate valves which are provided to permit the discharge of supernatant sewage back into the pump well could not be opened, so that it was necessary to pump the entire volume of liquid and sludge from each of the septic tanks. It was stated that the sewage and sludge was pumped to a large excavation about 6 feet in depth. After about two days, a certain quantity of chloride of lime was added to the mixture whereupon the earth originally excavated was filled in. The disposal of the sludge from the septic tanks by this method is stated to have been carried out without causing a nuisance. No notes were taken as to the actual quantity of sludge in the septic tanks, but rough measurements made during this investigation have indicated that the sludge accumulation has not been very great.

The results of the weir measurements indicated a sewage flow such that with only one septic tank in service the combined volume of sewage discharge by an alternating siphon and pumped to the septic tanks during such discharge, could not be reduced sufficiently to permit of its entire retention by one contact filter, even after the filtering material had been cleaned as was done in August, 1906. In view of the discharge of quantities of imperfectly purified sewage, the railroad officials were officially advised by the Secretary of the State Board of Health to make the necessary changes in the construction of the plant by enlargement or otherwise so that its efficiency would be improved and its operation be in accordance with that originally planned; to endeavor to decrease the quantity of the crude sewage or, in case neither of these two suggestions appeared feasible, arrange to make a temporary connection with the Collinwood sewerage and eventually to abandon the plant and cause the sewage to flow into the new intercepting sewer of the city of Cleveland.

It was found impracticable to make a material reduction in the sewage flow. As a temporary expedient until connection could be made to the Cleveland

sewers, the pipe on the force main to the pumps was changed so that both septic tanks would receive sewage simultaneously. This causes less sewage to enter a septic tank during the discharge of an alternating siphon and as the inspections of July 9th and October 17th, 1907, indicate, improves operating conditions somewhat, but the volume of sewage is still such that a certain quantity of imperfectly purified effluent is discharged through the effluent sewer.

Since the fall of 1096, as before stated, the plant has been under the supervision of the Chemist and Engineer of Tests, and under his direction the plant has received excellent care. At about monthly intervals certain tests have been made to learn the length of pumping periods and the length of the contact filter cycles. It is interesting to record that it was necessary to heat the pump house with a special steam line in order to prevent stopping the pumps by freezing of the ends of the air cylinders.

From the monthly records it appears that during December, 1907, about 5 inches of filtering material (200 cubic yards) was removed with a view to affording a greater retention of sewage by the contact filters and thus reduce the discharge of untreated septic sewage and increase the actual period of contact. It appears from the December records that the actual time of contact has by this means been increased from 14 to 25 minutes. The average rate of filtration is approximately 5,000,000 gallons per acre in 24 hours and corresponds to a population load of 38,000 per acre or 7,600 per acre-foot.

EFFICIENCY.

The features of operation, just described, have no doubt indicated that the efficiency of the plant in the purification of the sewage of the shops has not been so high as is desirable. During this investigation, owing to the operating conditions which have prevailed during the years 1906 and 1907, especially the fact which inspection alone demonstrated that at all times large quantities of practically untreated septic sewage have been discharged, together with the effluent from the contact filters, it was not thought necessary to collect samples to show the actual efficiency of the plant by means of analytical data. Two chance portions of two discharges from the septic tanks, and two similar samples of the effluent from two of the contact filters collected on the detailed examination of June 18-20, 1906, show the average condition of the sewage of the shops after it has passed the plant.

SUMMARY.

Summarizing the efficiency data available from inspections, it is apparent that the capacity of the plant has been exceeded for some time past. This condition is primarily due to the largely increased flow of sewage owing to the enlargement of the shops since they were first built and this fact brings out the important point that there is a limit to a plant arranged to be operated automatically beyond which it cannot be operated successfully without there be an increase in the size of the several units of which it is composed.

Throughout this investigation the officials of the shops have co-operated with the Board in the endeavor to improve the operation of the plant with a view to preventing the discharge of imperfectly purified sewage. Before the present largely increased volume of sewage flow was known, the material in the contact filters was entirely replaced in the hope of increasing their capacity, but this expedient did not prove successful as before stated. Changes were then made in the piping so that the sewage as pumped would discharge to both septic tanks at the same time, and while this change has greatly benefited conditions, and has

greatly reduced the quantity of unpurified sewage, which is discharged with the effluent from the contact filters, yet it has not been entirely successful in this regard. In view of these conditions, therefore, the recommendations already made by the Board that the plant be abandoned and that the sewage be permitted to flow into the sewers of the city of Cleveland, seems the most economical and most feasible plan to adopt for the future disposal of the sewage of the shops.

COSTS.

The constructional costs of this plant were $6,800. Prior to this investigation the cost of operation has been very low and has amounted practically to that entailed in the care of the mechanical details of the plant. These costs may be noted from the detailed items of recent maintenance, which are listed below. During 1906 and 1907, however, the operating costs have increased in view of the greater supervision which the plant has received. The cost of removing and replacing the contact filtering material and of cleaning the septic tanks was $1,039.88. Omitting this amount from the annual cost data, the yearly cost of operation according to the figures of 1907, as obtained from the Chemist and Engineer of Tests are in round numbers about $115. The monthly items of costs are approximately the following:

Janitor work	$2 10
Pump attendance	2 60
Tests of operation	4 50
Total	$9 20

The estimate of $115 includes estimated cost of repairs.
The detailed costs of renewals, etc., in 1906, were as follows:

TABLE NO. 99.

Detailed Costs of Renewals, Cleaning and Repairs in August, 1906.

Cleaning septic tanks	$163 60	
Excavation for sludge and sewage	189 50	
Total cost of sludge disposal		$353 10
Removal of filtering material (322 cu. yd.)	$209 19	
Relaying half-tile distributors	17 75	
Repairing siphon piping	28 50	
Replacing stone in contact filters, labor	152 45	
Filtering material	306 00	
Repairing plant cover	41 73	
Total cost reconstruction of contact filter	$755 62	
Credit old stone	111 60	
Net cost reconstruction of contact filters		$644 02
Repairs to pump house and pumps		42 76
Total cost of reconstruction and repairs		$1,039 88

The cost of removing 5 inches of the surface material of the contact filters in December, 1907, was $40.12, or about $1.54 per cubic yard.

TABLE NO. 100.

Results of Chemical Analyses.

Date 1906.	Hour of Collection.	Parts per Million.										
		Oxygen Consumed.		Nitrogen As					Chlorine.	Suspended Matter.		Putrescibility.
				Organic.		Free Ammonia	Nitrites.	Nitrates.				
		Total.	Dissolved.	Total.	Dissolved.					Total	Volatile.	
						Effluent Septic Tanks.						
June 20, 1906.....	7:24 A.-7:55 A....	32	.....	2.3	.....	3.8	0.00	0.0	30	68	50	.....
June 20, 1906.....	8:38 A.-9:10 A....	31	.....	3.6	.....	5.8	0.00	0.0	.....	60	50	.....
						Effluent Contact Filter No. 3.						
June 20, 1906.....	7:47 A.-8:17 A....	16	.....	2.4	.....	3.8	0.03	1.0	.....	35	24	+
						Effluent Contact Filter No. 4.						
June 20, 1906.....	8:59 A.-9:30 A....	19	.....	3.9	.....	5.4	0.09	0.7	26	42	32	+

OHIO QUARRIES COMPANY, NORTH AMHERST.

The Ohio Quarries Company operate large sandstone quarries in the village of Amherst, Lorain County, at a point about five miles distant from Lake Erie. The quarries were opened up about the year 1904 and the project as planned included the construction of several streets and dwelling houses and a hotel for the housing of the employes. It was originally expected that the population of this small settlement would be in the vicinity of 300. The present population, however, is only about 40. The plans included also a sewerage system for the collection of the sanitary sewage of the settlement, since all the dwellings were equipped with modern sanitary conveniences. The sewage flow on the basis of 40 gallons per capita was estimated to be initially about 6,000 gallons and to increase ultimately to 12,000 gallons. Water was supplied to the settlement from large reservoirs in the quarries.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

Available means of disposing of the sewage of this small community was Beaver Brook, a small stream flowing into Lake Erie about 3 1/3 miles from the village of Amherst and at a point about two miles west of the Elyria water works and filtration plant. With a desire to comply fully with the state law regarding the disposal of sewage with respect to the pollution of streams, the company provided for sewage purification and employed a sanitary engineer to prepare plans. Since this stream is grossly polluted by the sewage of the village of Amherst, it is evident that the direct discharge of sewage from this small community would probably not have serious effect upon the waters of Beaver Creek nor upon the operation of the Elyria filtration plant. This example of the establishment of a sewage purification plant at an isolated small community is of special significance in line with the progress in the sanitary betterment of all surface waters.

Plans for this plant were presented to the State Board of Health and were approved in Nov., 1904, provided "that sand filters satisfactory to the State Board of Health be added if deemed necessary by said Board after the plant had been put in use." As proposed, the plant comprised a covered septic tank supplemented by an erected continuous filter constructed of coarse material.

INSPECTIONS.

This plant was visited in 1906 on April 14 and August 25, and in 1907 on Oct. 22. No detailed examinations were made.

DESCRIPTION OF PLANT.

The sewers are constructed on the combined plan and comprise several hundred feet of 6-inch pipe. In dry weather the sewage is discharged into a septic tank, whence it flows on to a continuous filter. The plant constructed in the year 1904, receives sewage from nine dwellings and a hotel, of which the total population is about 40.

Overflow Chamber.

The crude sewage passes first into a covered concrete overflow chamber for use in times of storms. The chamber is 3x4 feet in plan and 3 feet deep. For dry weather conditions, a channel is provided 3 feet deep discharging into the septic tank through a 6-inch pipe and separated from the 10-inch storm water

overflow by a screen composed of six ½-inch iron bars set 1 inch c. to c. vertically. At the outlet of the chamber adjacent to the septic tank, a slot is provided to receive a gate whereby the flow of sewage may be excluded from the septic tank.

Grit Chamber.

Sewage without preliminary screening is received into a compartment of the septic tank which may be termed a grit chamber. This is 3x4 feet in plan, 4 feet deep and of 360 gallons capacity.

Septic Tank.

The plant contains one septic tank of concrete. The walls of the tank are 12 inches thick and the bottom is 6 inches. The tank is covered with a roof constructed of expanded metal and concrete with a thickness of 6 inches. There is a head room of two feet from the flow line to the roof. The tank is practically inaccessible for ready inspection, although three 24-inch manholes are provided, one over the grit chamber, one at the first baffle and one over the outlet of the septic tank. The tank is 6 feet by 24 feet in plan and 10 feet deep and has a capacity to the flow line of 8,600 gallons. The depth at the flow line is 8 feet.

Inlet and Outlet. The inlet to the tank comprises a straight 6-inch pipe 4 feet long, which terminates in a channel 24 inches wide at the outlet of the grit chamber and increases to a width of 36 inches at the entrance to the septic tank proper. The outlet of the septic tank is a 9-inch channel across the tank and is formed by a 6-inch concrete shoulder. From this channel leads a 6-inch elbow and about 18 feet of iron pipe carried on 16 per cent grade to the continuous filter.

Baffles. Three concrete baffles are provided. The first is 4 feet from the inlet end and extends 3 feet below the flow line, and is 4 feet high and 6 inches thick. The top of the baffle is 12 inches below the roof of the tank. The second is a submerged baffle 6 feet 6 inches high and 6 inches thick and is 18 feet 3 inches from the inlet and extends from the bottom of the tank to 2 feet below the flow line. The third is a surface baffle similar to the first and is 5 feet high and 6 inches thick. It is located 2 feet from the outlet end of the tank and is 12 inches below the roof and is submerged to a depth of 4 feet.

Sludge Drains and Method of Control. There are no facilities for removing sludge and the floor of the tank is level. The flow to and from the tank is by gravity and is not controlled. It is interesting to note that the tank is on the side of a hill and only a part is in excavation.

Filters.

From the septic tank the sewage flows on to a continuous filter 18 feet square or 0.00743 acre. This filter has a total depth of 10 feet. It is contained in an erected dry masonry tank, three walls of which are 12 inches thick. The fourth or effluent wall is a column 18 to 36 inches in thickness. The bottom is of 6-inch concrete and is laid on an 8-inch broken stone base. The floor of the tank slopes 6 inches in 18 feet or 1 in 36.

Filtering Material. The filtering material comprises several layers of crushed sandstone which ranges in size and depth as follows:

Upper 36 inches. ½-inch.
Next 12 inches, 1½-inches.
Next 36 inches, 2½-inches.
Bottom 36 inches, 3-4 inches.

Underdrains. The 3 feet of coarse stone on the bottom serves as an underdrainage system.

Distribution Devices. The filter receives the continuous direct flow from the septic tank by means of a main carrier which is a concrete channel 8 inches deep and of trapezoidal cross section. The bottom of the carrier is 27 inches in width and its length is 17 feet. It is covered with 2-inch plank. The trough is anchored to the walls of the filter. From both sides of the carrier lead nine 1-inch iron pipes 4 inches long. These discharge on to lines of 6-inch half-tile laid at right angles to the main carrier and extending completely across the filter. These lateral distributors are 2 feet apart and are set directly on the filtering material. The tiles are laid with uncemented joints and are about 3 inches beneath the surface of the filtering material.

Effluent Discharge. The effluent from the filter flows into a concrete channel of trapezoidal cross section, which is 28 inches wide at the top and extends the entire width of the filter. In the center of this channel is a 6-inch pipe which leads to the creek about 200 feet distant. The nearest house is about 1,000 feet from the plant. Local conditions are such that there is no liability of interference by floods.

SEWAGE FLOW AND CHARACTER OF CRUDE SEWAGE.

No gagings of the sewage flow are available, but from inspections it appears that the average flow of domestic sewage is from 4,000 to 5,000 gallons daily. On the visit in the fall of 1907, however, it was stated that it is the practice to pump through the sanitary sewers daily about 15,000 gallons of clear water. During storms, of course, the flow of sewage is greatly increased. It is to be noted that the volume of sewage is much less than that which formed the basis of the design, since only a part of the contemplated settlement was actually built.

During dry weather the sewage is entirely domestic, but on account of the daily practice of flushing the sewers is, of course, highly diluted.

OPERATION AND EFFICIENCY.

No special supervision has been given the plant, although occasional visits are made by an employee of the quarries company. During three years of service, the septic tank has not been cleaned and inspections made during this investigation have indicated that there is very little sludge accumulated and no scum. The septic tank has required practically no attention. In view of the small volume of sewage, the period of flow in the tank is perhaps 31 hours, prolonged at times as much as 48 hours or more. This fact, however, has had apparently no appreciable effect upon the purification effected by the continuous filter.

The greatest criticism with reference to the operation of the plant relates to the clogging of the main and lateral distributors on the filter. On all of the visits, the main distributing trough was completely clogged, also the lateral half-tile and generally the sewage was being applied to only a small part of the filter, which, of course, received an excessively large volume of sewage. On the three visits, the effluent was putrescent, possessed a decided odor and the resulting purification was very unsatisfactory. Furthermore, due to clogging and because of the poor distribution, the effluent from the filter was flowing from one corner and not through the effluent channel. Several suggestions were made during the visits with a view to improving the efficiency of the plant. It was suggested that an attendant be engaged to visit the plant daily, and see that the main and lateral distributors were kept free from clogging. It was further advised that a dosing tank operating a sprinkler nozzle would decidedly improve the efficiency of the distribution and the general character of the effluent. Practically none of these suggestions were carried out, and as noted on the final inspection in the fall of 1907, the purification effected was very unsatisfactory.

SUMMARY.

The poor results which have been obtained from this continuous filter, even though it has received the sewage at the rate of only perhaps 5,400 persons per acre, or 540 persons per acre-foot, are probably to be ascribed chiefly to the poor distribution and also to lack of supervision. The rate of filtration has ranged aproximately from 670,000 to 1,000,000 gallons per acre in 24 hours. Experience with small experimental plants operated continuously and in which distribution has been attempted by means of half-tile troughs, has shown that this method of distribution at best is rarely successful. It depends for its success, of course, upon so adjusting the troughs that they will at all times be accurately level. Since the material in the filter compacts after service, the troughs soon cease to be in adjustment and inferior distribution results. Furthermore, it is a difficult matter to prevent clogging of 1-inch pipes such as are used at this plant to conduct the sewage from the main to the lateral distributors.

To improve the efficiency of the purification of the sewage it would be advisable to make the changes in the method of applying the sewage as already outlined and it would be further desirable that the plant be inspected daily by a caretaker appointed for that purpose. Provided these suggested improvements are carried out, it is probable that the sewage will be purified to a degree sufficient to meet local requirements and that the construction of the subsidiary sand filters forming a part of the conditions of the approval of the State Board of Health, will then be unnecessary.

COSTS.

From information obtained from the treasurer of the Ohio Quarries Company, it appears that the cost of the plant was about $5,000. The sewers and house connections cost $2,381.91, and septic tank and filter cost $2,791.22.

Operating expenses are practically nothing.

HARDIN COUNTY INFIRMARY, KENTON.

The infirmary of Hardin County, which has a population of about 100, is about two miles northwest of the city of Kenton, near the Scioto River. The water supply of the institution is derived from wells and since the year 1898 the buildings have been equipped with modern sanitary conveniences.

In the year 1896, the attention of the State Board of Health was called to the very unsanitary conditions which existed at this institution. The Board investigated the matter and subsequently recommended extensive sanitary improvements. In October, 1897, as a part of the contemplated improvements, plans were presented to the State Board of Health for the purification of the sewage of the infirmary by means of a system of sub-surface irrigation. The plant as proposed comprised a flush tank or receiving reservoir, a basket screen and several hundred feet of vitrified sewer pipe, which was arranged to carry the sewage to the irrigation field. This field at a depth of 16 inches was underdrained with tile laid with open joints and beneath these drains was a second system of pipes laid from 3 to 3 feet 6 inches below the surface of the ground. The second set of drains was for the purpose of lowering the general ground water level and of receiving the purified sewage which was carried to the Scioto River in a sewer some 1,700 feet in length. The plant was designed for a population of about 75

and an ultimate population of 140. The quantity of water used was at that time about 10 gallons per capita and the ultimate consumption was taken as 50 gallons per capita or about 7,000 gallons daily.

The plant was first operated in the year 1898. The underdrains in the absorption field comprised 15 parallel lines of 4-inch tile, 400 feet long and about 15 feet apart. The second system of drains were soft tile from 4 to 6 inches in diameter. The soil in the absorption field was largely composed of clayey material and had a tendency to compact rapidly. The mechanical analysis of the soil showed an effective size of 0.02 m.m. and a uniformity coefficient of 15.

This plant was visited once during this investigation, namely, on October 5, 1906. It was found that the plant had been abandoned about five years after it was constructed. The subsurface tile became clogged, sewage appeared on the surface of the ground and it was not possible to cultivate the absorption field, as has formerly been the case. To again make available this tract of land, the county commissioners decided to abandon the purification of the sewage of the institution and subsequently built a 20-inch tile which is connected with the dosing tank and through which the sewage, without treatment, flows directly into the Scioto River.

Although successful in some instances where sandy soil is available, experiences at this plant have shown that the disposal of sewage by a subsurface irrigation system cannot be satisfactorily carried out in a clayey soil without clogging, and a frequent necessity of cleaning and relaying the underdrain tile.

WASHINGTON COUNTY INFIRMARY.

This county institution is about three miles from the city of Marietta and is on high ground which drains into Duck Creek, a small stream which flows into the Ohio River about ¼-mile north of the intake of the Marietta waterworks. The average population of the institution is about 80. Its water supply is chiefly obtained from the city of Marietta and the daily consumption from this source is estimated at about 2,500 gallons. There is an additional slight consumption of rain water.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

Modern sanitary conveniences had been in use for some years prior to 1902, and the resulting sewage was allowed to flow without treatment into a small brook which leads to Duck Creek. During dry seasons this run became quite offensive and so many complaints arose, owing to the nuisance thus created, that in the fall of 1902 the infirmary board decided to provide a means of purifying the sewage of the institution. The proposed plans as submitted to the State Board of Health for approval, contemplated treatment in a septic tank followed by contact filters. Owing to adverse weather conditions during construction, the completion of the plant as originally designed was so long delayed that several months after construction work was begun the infirmary board asked permission of the State Board of Health to construct the septic tank only. It was stated that the nuisance due to the discharge of crude sewage was serious only for short periods of intermittent dry weather, and that it was the opinion that a septic tank alone would serve to abate the nuisance. In reply to this request for constructing a part of the plant, with a view to determining whether a septic tank alone would be sufficient to alleviate the local nuisance, the Board voted favorably, with the

provision, however, that the complete plant as designed was to be installed if the nuisance was not entirely abated, or whenever the State Board of Health should so require.

INSPECTIONS.

One visit of inspection was made to this plant, and it occurred on August 3rd, 1906.

DESCRIPTION OF PLANT.

In accordance with the above approval of the State Board of Health, the present sewage purification plant was installed in the fall of 1902. It consists only of a septic tank, 10 feetx20 feet in plan and from 4 feet to 4 feet 4 inches deep. The tank is constructed of brick and has 12-inch walls and a 6-inch bottom. Extending upwards from the bottom to a height of 4 feet, the walls are 2 feet thick. The thickness is then decreased to 12 inches at the top, at which point the wall forms a support for the roof. The tank is covered with a wooden pitched roof and is practically inaccessible for inspection. Sewage flows into the tank through a 12-inch vitrified sewer pipe, which has the bell end on the inside. The invert of the inlet pipe is 2 feet from the bottom of the tank and 12 inches from the west side. The outlet is a 6-inch elbow located on the longitudinal center line of the tank and 12 inches below the flow line. The flow line of the tank averages 2 feet and the capacity of the tank is about 3,000 gallons.

At the outlet end, at the west side of the tank, there is a sludge drain which is controlled by an 8-inch gate valve. The invert of the drain is flush with the bottom of the tank. From inlet to outlet the floor of the tank slopes 1 in 60. A 10-inch overflow is provided on the east side of the tank near the outlet end. The invert of this overflow is 12 inches below the top of the tank. Sewage from the septic tank flows into a brick chamber 4 feet 6 inchesx3 feet 11 inches in plan and 2 feet deep. This chamber is divided into two compartments by a brick wall which was originally intended to be pierced with piping for the control of the contact filters, which were included in the complete design. At the present time the sewage flows through two lines of 6-inch pipe, each about 3 feet long, situated at the east and west corners of the valve chamber, respectively. The tank is located about 1,000 feet from the nearest house.

SEWAGE FLOW.

The volume of sewage at the plant has been estimated from the records of the Marietta waterworks. The water consumption in 1907 was about 2,500 gallons daily, or 31 gallons per capita. Some roof water has in the past entered the sanitary sewers, but in the spring of 1907 the storm water is stated to have been directed to other channels.

OPERATION.

Since construction, the plant has received little or no attention. When inspected, the outlet of the septic tank was plugged, portions of the outlet tile were broken, and sewage was flowing over the sides of the tank. Examination showed that perhaps 60 to 70 per cent. of the tank was filled with sludge. Gas formation was active in the sludge and the effluent was black and possessed a strong odor noticeable 200 feet distant. It was stated that no sludge had been removed from the septic tank during its four years of service.

The Board subsequently advised that the tank be cleaned. By correspondence it was learned that this was done in the spring of 1907. Advantage was taken

of a very high flow of sewage during a severe thunder storm, and the sludge was practically flushed out of the tank. It was stated that soil and chips from the wood-yard formed a considerable part of the sludge. The period of flow is about 29 hours and the linear velocity averages about 0.06 m.m. per second.

EFFICIENCY.

There is, of course, no actual purification of the sewage of the institution. As to the question of the abatement of the former nuisance from the discharge of crude sewage, a resident on the hillside about 200 yards below the septic tank stated that at times considerable odor arises from the septic effluent, especially on warm days in summer. Inspection showed marked evidences of pollution in the brook below the plant. It appears, therefore, that were the population adjacent to the infirmary greater than is here the case, it would unquestionably be advisable to insist upon a thorough purification of the sewage. The present plain septic tank treatment does not alleviate the local nuisance entirely, as it serves merely to retain the coarser solid matters.

COSTS.

The first cost of this simple sewage plant was about $269, in detail as follows:

Brick and cement	$ 81 26
Labor	64 50
Incidentals	34 55
Engineering	89 00
	$269 31

SUMMARY OF EXAMINATION OF SEWAGE PURIFICATION PLANTS.

In concluding this report it is purposed to review all evidence obtained during this investigation in its relation to the general problem of sewage purification, especially with reference to Ohio conditions. The discussion will embrace (1) Conditions leading to the installation of sewage purification plants; (2) General character of the sewerage systems; (3) Location of the sewage purification plants; (4) Volume and composition of the crude sewage; (5) Purpose and efficiency of the different types of preparatory treatment; (6) Methods of operation and the results accomplished by the different finishing processes; (7) Supervision and management; (8) A resume of installation and operating costs and a tabular statement of the leading features of the thirty-eight sewage purification plants studied during this investigation.

CONDITIONS LEADING TO SEWAGE PURIFICATION.

The great variety of methods of sewage treatment found in Ohio has already been mentioned and the tabulated statements at the close of the introduction show their general nature in sufficient detail, so that it is unnecessary to dwell further upon this phase of the Ohio sewage problem.

In 1905 there were twenty-four plants in operation serving an estimated

population of about 54,000. During this investigation thirty-eight plants were in operation, eight were under construction and some fifty or more proposed plants have been submitted to the State Board of Health for approval. The plants now in operation and under construction serve an estimated population of nearly 270,000, or 12 per cent of the urban population, or 7 per cent. of the total population of the state. These figures indicate the very rapid recent development of sewage purification in Ohio.

A review of the causes which have led to the establishment of the sewage purification plants now in operation and described in this report, shows that their installation is attributable to one or more of the following conditions:

1. Prevention of local nuisance.
2. Suits on the part of lower riparian owners.
3. Protection of a public water supply.
4. Protection of dairy interests.

Of the thirty-eight plants discussed in this report, thirty-five or 92 per cent were constructed with a view to preventing a local nuisance, since the volume of flow in the nearest watercourse was insufficient inoffensively to dilute the sewage. This condition arises in two cases, one, the increased use of sewers already constructed, and the other, the contemplated construction of a system of sanitary sewers and the absence of suitable dilution facilities even during the early history of the sewage system. Plants constructed to abate an existing local nuisance are the following: Clyde, Fostoria, Glenville, Mansfield, Xenia, Fairmount Children's Home, Montgomery County Infirmary, Gallipolis State Epileptic Hospital, Hardin County Infirmary, Lancaster Boys' Industrial School, Washington County Infirmary Marietta, Massillon State Hospital, Soldiers' and Sailors' Home Sandusky, Toledo State Hospital and Trumbull County Infirmary. Plans designed to prevent an expected local nuisance are as follows: Alliance, Ashland, Canton, Delaware, East Cleveland, Geneva, Kenton N. District, London, Marion, Oberlin, Plain City, Shelby, Collinwood L. S. & M. S. Railroad Shops, Gallia County Infirmary, Mansfield State Reformatory, State Institution for Feeble Minded Youth Morgans, Ohio Quarries Company North Amherst, Warrensville Cleveland Tuberculosis Farm Colony and Wayne County Children's Home.

In five, or 14 per cent of the plants examined, their installation is due to threatened or instituted legal measures on the part of lower riparian owners usually residing but a short distance below the proposed or existing sewer outfall. Plants in this group are those at Alliance, Canton, Clyde, Mansfield and Trumbull County Infirmary.

For the protection of public water supplies there have been provided seven plants, namely, those at Lakewood, Marion, Westerville, Fairmount Children's Home, Lancaster Boys' Industrial School, Trumbull County Infirmary and Wayne County Children's Home. The plant at the Washington County Infirmary, Marietta, although not included in the above list, has a marked influence on the pollution of Duck Creek, seriously contaminates the Ohio River water and at times of flood flows appears to have some bearing upon the operation of the Marietta filtration plant. While to secure a maximum of protection of public water supplies from contamination the ordinary methods of sewage treatment are inadequate, yet in the case of the plants just mentioned, the visible pollution of the stream is thus prevented and its more thorough self purification is thus made possible.

While the relation between the sewage plants and the dairy interests of the state has not been especially studied during this investigation, yet it is apparent that in some of the rural districts the waters of the smaller streams are much cleaner than would be the case were the wastes allowed to discharge in a raw state. In this sense, some of the plants indirectly improve conditions relative to the large dairy interests in Ohio; the Shelby plant particularly is a case in point.

GENERAL CHARACTER OF THE SEWERAGE SYSTEMS.

Of the 19 municipal plants studied, 16 or 84 per cent have sewerage systems on the separate plan. In a number of these cases, however, roof connections and high ground water leakage due usually to faulty sewer construction, cause the quantity of sewage to be greatly increased in times of storms and wet weather. So soon as the purification of the sewage becomes necessary, the exclusion of ground and surface water becomes of greatest importance. Especially is this important where automatic devices are in use for applying the sewage or where it is necessary to resort to pumping.

As a remedy for conditions such as exist in Ohio, where the sewerage systems are ostensibly on the separate plan, it is recommended (1) that the sewers be underdrained; (2) that joints be made as tight as practicable where the sewers are laid in wet ground; (3) that special attention be paid to the proper shaping of the bottom of sewer trenches and to back filling in order to insure firm foundations, and (4) that careful inspection during construction be supplemented by careful oversight of all future connections to the system, especially the feature of down spouts. It is particularly desirable, as is true in a few places, that accurate records be kept by the city or village engineer of the location of all sanitary connections to the sewer system. All points of connection should be accurately located on a map of the system, or by means of a card index for ease of future reference, especially for locating points at which new connections can most readily be made. There appears to be a considerable laxity in the smaller towns regarding connections to the sewers for sanitary purposes and in many cases there are no records of such connections, and it has not been possible to obtain more than a rough estimate of the actual number of persons served by the sewage purification plant.

CHOICE OF SITE OF PLANT.

Of the 19 municipal plants studied, 16 or 84 per cent, are so located that the sewage reaches them by gravity. The location of a sewage purification plant, with reference to the mean low water in the adjacent stream, has been found to be a very important feature with regard to the successful operation of a plant and the satisfactory purification of the sewage at all times. In some instances plants have been constructed on sites at such a small elevation above that of the mean low water of the adjacent stream, that a slight rise in the stream is sufficient to render the operation of the plant temporarily impracticable. Under such conditions, the crude sewage of the city is by-passed without treatment. There are seven plants now in operation which are unfortunately located with respect to flood flows in the adjacent stream (Clyde, Delaware, Fostoria, Plain City, Shelby, Oberlin and Toledo State Hospital.)

On account of conditions just discussed, in 11 of the 38 plants studied, it is necessary to allow the crude or partially settled sewage to flow into the neighboring stream without further treatment. A large majority of the sewage purification plants have been installed to prevent a nuisance due to the pollution of the local watercourse, so that the direct discharge of organic matter during high flows is unobjectionable only when there exists dilution sufficient to oxidize the organic matters and render them non-offensive. From a hygienic standpoint, however, the practice may not be without criticism, especially with relation to the protection of water supplies below the plant. It is, therefore, necessary to consider fully all phases of the problem before suggesting a plant so located that by-passing during storms will be necessary.

VOLUME OF SEWAGE.

It is, of course, evident that the quantity of sewage flow is affected largely by weather conditions. In practically all of the municipal sewage purification plants studied during this investigation, there is a decidedly increased flow during storms and long continued wet weather when the ground water level is high. The dry weather rate of flow of the 19 municipal plants ranges from 45 to 350 gallons per person tributary. The volume of sewage flow shows wide variation during storms and this is often true even in the case of those municipalities whose sewerage systems are on the separate plan. Information in condensed form as to the dry weather flow and the maximum flow of sewage at the municipal plants is shown in Table No. 106.

The sewage flow at the institutional plants studied ranges from 18 to 211 gallons per capita. While ordinarily 30 gallons per capita may be taken as a fair figure for estimating the water consumption of institutions, yet it appears that at the larger institutions, especially those for the care of the insane, this figure is generally very much higher (Toledo 150, Gallipolis 122, and Massillon 137 gallons), due largely to the fact that it is necessary to use automatically flushed closets which, of course, consume large volumes of water. The water thus used is also further supplemented by extensive laundrying and bathing operations. In a few cases the volume of flow at institutions also is greatly increased during storms, since the roofs of the buildings are connected to the sanitary sewers for flushing purposes. This practice while feasible in some instances, cannot be generally recommended, since the increased flow of sewage interferes greatly with the normal operation of the sewage purification plant.

COMPOSITION OF CRUDE SEWAGE.

All of the municipal sewages of the state are strictly domestic with the exception of Fostoria, where some acid iron wastes are admitted into the city sewers. There is, however, a wide range in the general character of the sewages, especially the quantity of suspended matter, the freshness as indicated by the presence of dissolved oxygen and nitrites and nitrates, and the appearance of the liquid as regards colloidal matters and those substances which impart to the sewage a milky appearance. Almost all of the detailed examinations during this investigation were carried out during dry weather conditions, that is, when there was no actual rainfall during the test, but in some instances previous wet weather had raised the ground water table and thus increased the leakage into the sewers. From information available from this investigation, it appears that the general character of the sewage is in a large part affected by the degree of dilution which it sustains. The suspended matters in the municipal sewages ranged from 23 (Plain City) to 213 (East Cleveland) parts per million (0.10 to 0.89 ton per million gallons) for the average for 24 hours and in the strictly day sewage, from 20 (Mansfield) to 242 (East Cleveland) parts per million (0.08 to 1.01 tons per million gallons). The institutional sewages showed a wide range in suspended matter in the average sewages from 31 (Gallipolis State Epileptic Hospital, Cottage I) to 512 (Montgomery County Infirmary) parts per million (0.13 to 2.14 tons per million gallons). In some of these cases the rough preliminary treatment removes a part of the coarser suspended matters. Thirty-two of the sewages examined show evidences of collodial suspended matter, but in the case of the sewages of Clyde, Delaware, Geneva, Lakewood, Plain City and Shelby, there is so much dilution with ground water that the suspended matters are granular and have a high subsiding value. In these instances the sewage is virtually a clear liquid which contains fairly large quantities of suspended particles of very irregular shape and thus differs materially

from that of a city or village where the dry weather flow is normal. Accompanying these peculiar sewages are high nitrites, nitrates and dissolved oxygen, or in other words the liquid portion of the sewage is almost non-putrescible. The sewages of this type make possible an efficient purification on a continuous basis even where the plants could not be successfully operated were the sewage more nearly of normal composition (Clyde, London and Plain City.) The sewage of Clyde furnishes the best example of this type of sewage, as it invariably contains dissolved oxygen and nitrates. A reference to the detailed report on this village will show what an important bearing has the nature of the sewage upon the efficiency of the sand filters as there operated.

Institutional sewages differ from those of cities and villages, chiefly owing to the fact that they contain more coarse inorganic and organic suspended matter, soapy wastes and grease. Large quantities of rags, paper, clothing and other debris find their way into the sewers of institutions and must be removed before the sewage is purified. The low per capita water consumption in the case of the smaller institutions further renders the sewage stronger and perhaps more difficult to purify than that of municipalities.

PREPARATORY TREATMENT.

The discussion of the preparatory treatment of the crude sewage of the state is based upon the results obtained at 17 of the municipal and 6 of the institutional plants. The evidence will be reviewed under the respective headings: Screening, chemical precipitation, plain sedimentation in grit chambers and in settling or septic tanks, respectively.

SCREENING.

In a majority of the sewage purification plants in Ohio the crude sewage first receives screening as a rough preparatory treatment. This process is by no means so thorough as is the case in the larger plants, particularly abroad, but is confined to very crude straining through screens of different kinds and with open spaces which range from ½ to 6 inches. In six of the 19 municipal plants some sort of screening is provided. Very little attention is paid to the operation of the screens and practically no reliable data are available from this investigation as to the quantity of screenings produced. The greater number of municipal plants use screens constructed of iron bars of circular or rectangular cross section. They are usually slightly inclined to the vertical and are placed in specially constructed channels or chambers. At one or two places, notably at Marion, an attempt was made to use a diamond mesh screen, but it was not found practicable to continue its use, since a screen of this character clogs very rapidly and is somewhat difficult to clean. In connection with durability and ease of cleaning, available information suggests that round iron bars, perhaps ¼ to ½-inch in diameter, can most advantageously be used in the construction of screens. From ½ to ¾-inch clear opening is the usual spacing employed.

In the institutional plants in most cases some form of screening is provided. The types of screens vary from the bar screens, just discussed, to screen baskets provided with means for ready removal (Gallipolis) and upward flow screens as at Mansfield State Reformatory. Screens are a very essential part of a sewage purification plant in connection with institutions, since so much coarse material finds its way into the sewers. The basket screens, however, generally have such large open spaces that there is practically little screening similar to that which is to be found at the larger plants where the operation of the screens is carefully watched and where the screening removes no inconsiderable quantity of the sunspended matter of the crude sewage. In seven of the institutional plants there

are no screens provided, and as a result the purification devices present a very unsightly appearance and are frequently clogged with paper, rags and other fibrous material.

The disposal of the screenings in the Ohio plants deserves very little comment save experiences at Mansfield State Reformatory. At this plant the upward flow screens and screen chamber were cleaned twice daily by opening a sluice gate at the bottom of the chamber whence the mixed screenings and sewage flowed through a second coarse screen thence to the adjacent stream. The upward flow screen clogged rapidly and intercepted large quantities of putrescent material and the practice caused such a decided pollution of the Rocky Fork that in the fall of 1907 a filter constructed of fine cinders was provided to receive the strong sewage by-passed during the cleaning of the screen. This experience suggests that there is no advantage and in fact a disadvantage in providing upward flow screens since they clog rapidly and intercept material which should be carried on to the finishing devices. At most places, the screenings are usually removed at occasional intervals and are either burned under the boilers or buried. In a number of the smaller plants, heaps of screenings present a very unsightly appearance, a criticism which can easily be overcome by proper attention to the operation of the plant.

Chemical Precipitation.

Chemical precipitation, one of the oldest types of sewage treatment, is exemplified in Ohio by the plants at Canton, Alliance and in part by those at Glenville and Oberlin. The Canton plant was the first built in Ohio and it was constructed when but little was known regarding the bacterial treatment of domestic sewage. The treatment employed at this plant and at that of Alliance which was built a few years later, comprises chemical precipitation alone. This investigation has shown that the process as carried out at these two places offers very little advantage over plain sedimentation. Both with and without chemicals the effluent has been found to contain only from 40 to 50 parts per million (about 0.2 ton per million gallons) suspended matter although the results in terms of percentage of removal of suspended matter are only about 50 per cent., a figure which is decidedly less than the generally assumed efficiency of chemical precipitation. These apparently low results, particularly at Canton appear to be due to the decided increase in the sewage flow during recent years, to the corresponding decrease in the period of flow, to the increase in the actual linear velocity through the tank and to the general weakness of the crude sewage. The quantity of lime used on week days has averaged 13.6 grains per gallon, or 1 ton per million gallons.

The results at Canton and at Alliance have also shown the well known solvent action of lime on suspended organic matter, with a result that the effluent from a chemical precipitation plant is often times stronger organically and hence more offensive than is the crude sewage after the removal of the suspended matters by plain sedimentation alone. The result of lime treatment at both Canton and Alliance, is, of course, merely a rough clarification and the production of a sewage effluent which is ill smelling and such as to cause a decided nuisance. At Canton facilities for dilution are such that no complaints have been entered in recent years, although one inspection showed cause for complaint, but at Alliance the offensive condition of the shores of the Mahoning River immediately below the plant has given rise to frequent complaints.

Aside from the fact that chemical precipitation is merely a preparatory treatment, the process entails the production of large volumes of highly putrescent sludge, the disposal of which is a difficult problem. Sludge pressing formerly carried out at Canton and Glenville has been abandoned, but is still practiced at the Alliance plant. Here there is produced daily about six tons of pressed

sludge cake. The cakes are dumped on the banks of the Mahoning River and are removed from time to time and are used for fertilizing purposes. The actual pressing of the sludge is a very noisome operation, but when pressed, the cakes may be allowed to accumulate without danger of nuisance from odors. At Canton and at Glenville the sludge is dumped on to land where the liquid portion is allowed slowly to seep away. In both cases the practice produces nuisances from odors. The Glenville plant was abandoned in August 1907, but the Canton plant is still in operation. It is probable, however, that the rapid growth of the city will demand a more thorough treatment than can be procured with the rough clarification by lime there practiced for eight months of the year.

In the case of Glenville and Oberlin, chemical treatment is supplemented by devices for producing a non-putrescible effluent. The plant at Glenville offers no unusual features and its general condition before its abandonment was substantially similar to that of the Canton and Alliance plants, particularly with regard to the greatly increased flow of sewage and the poor resulting efficiency of lime treatment. At Oberlin, however, where the sewage is treated with both copperas and lime, conditions are essentially different, since the Oberlin sewage is soft and contains few of the hardness constituents, which as Columbus experience indicates, greatly complicate the proper action of lime in securing the most efficient results in its use as a precipitant for domestic sewage.[1] The Oberlin method of applying iron as copperas to the sewage at one of the laterals farthest from the outfall followed by lime at a point on the trunk sewer below the entrance of the last lateral, is perhaps unique in the history of the chemical precipitation of domestic sewage. As has been discussed, it is the Oberlin practice to apply sufficient lime to maintain a small quantity of normal carbonates in the crude sewage as the latter reaches the sewage purification plant. The method of applying the chemicals, however, is somewhat crude and since there are no mechanical devices for agitating the coagulant solutions, the rate of application of the chemicals is very irregular and their efficiency is variable. At times there is a very satisfactory coagulation at Oberlin and an unexpectedly high purification merely by the passage of the lime and iron treated sewage through the shallow settling tanks and over the grass land, more frequently, however, the irregular application of the chemicals fails to afford the proper degree of coagulation and poor results are obtained in subsequent purification as a study of the Oberlin plant will show.

As a preparatory process for the treatment of crude sewage, available information appears to be strong that it is more advantageous to rely on the more modern processes of plain sedimentation, owing to the expenses entailed in the use of chemicals, on account of the troublesome accumulation of sludge, and the difficulties which attend subsequent treatment on devices for purification.

Grit Chambers.

Following screening, in 8 of the 38 plants studied the sewage is treated in small tanks, commonly called grit chambers which are intended to remove only the heavier mineral matters. To insure the selective deposition of mineral matters only, it is obvious that the rate of flow or more properly the linear velocity must be sufficient to prevent the precipitation of the coarser organic matters. In practically all of the Ohio plants where provisions are made for the preliminary interception of grit, the sewers are on the separate plan and except occasionally there is very little mineral matter in evidence. A careful examination as to the efficiency of the grit chambers in Ohio plants brought out the fact that they are a detriment rather than an advantage in the subsequent treatment of the sewage by sedimentation in septic tanks since they intercept large quantities of putrescent

[1] Johnson, George A. Report on Sewage Purification at Columbus, Ohio, 1905.

material which properly should not be deposited in a grit chamber. The sludge formed in these tanks, notably at Ashland, East Cleveland, Mansfield State Reformatory and Marion necessitates frequent cleaning and gives rise to decided odors. A study of the tabulated statement at the close of this report will show that in practically every instance, the velocity in the grit chambers is so low that they intercept a large proportion of putrescent material rather than the mineral matters carried by the crude sewage. Available evidence suggests that material of a heavy nature can to the best advantage be intercepted in the first compartment of a septic tank and it seems to be clear that a provision of this character will not greatly interfere with the operation of the septic tank and will not have a great effect upon the frequency of obligatory cleanings. In only one instance, namely Lakewood, would it appear desirable to provide for the interception of sand and mineral matter, and at this place it will be recalled that a large volume of storm water is admitted into the sanitary sewers.

Settling or Septic Tanks.

Sedimentation of the crude sewage in settling or septic tanks is the most common preparatory process employed in the Ohio plants. There are 19 septic tanks in operation at the present time, and they range in capacity from 2,300 to 1,000,000 gallons. While a majority of these tanks were originally arranged for periods of flow from 16 to 24 hours, increasing sewage flow and other conditions which have been described in detail in the individual reports, have greatly affected the actual periods of flow which now prevail and in some instances the time of passage through the tanks is very small. The data in regard to the flow periods of the septic tanks in the plants studied are summarized in Tables Nos. 106 and 107, at the close of this report. These periods range from a minimum of 0.5 to a maximum of 31 hours. In the most recent designs, an 8-hour period is generally provided and such was the period adopted at Columbus from the result of the thorough experiments there made.

Covers. Of the 19 septic tanks in operation, 15 or 79 per cent. are uncovered. Information available from this investigation indicates that there is practically no gain in efficiency due to provisions for covering a septic tank. In some instances, notably at Ashland, the covering of the septic tanks has resulted in minimizing nuisances due to odors. The question of covering a septic tank apparently cannot be decided once and for all, but is perhaps controlled by the location of the plant and the general character of the sewage to be treated. In case the sewage is of such a nature that its retention in a septic tank will result in the formation of a permanent scum, there appears to be some advantage in protecting the scum from the weather, otherwise a nuisance from odors may be created (Ashland) since the crude organic matters of which the scum is composed do not have an opportunity to oxidize when they are periodically subjected to the action of rain, snow and wind. A number of the covered tanks are provided with wooden pitched roofs, or flat concrete roofs with very small head room so that it is difficult to examine the tank, especially to determine the degree of sludge accumulation. In order to facilitate inspection and examination, this investigation suggests that whenever possible the covers or roofs over septic tanks be constructed so that the tanks are readily accessible. In case a high covering is not permissible, as at Marion, accessibility may be obtained by providing a number of manholes as in several of the Ohio plants, notably at Lakewood and Mansfield. In the probable event of an increasing demand for more thorough supervision, more intelligent management, frequent inspection and examination by state and municipal authorities, the feature of accessibility becomes more and more important and should receive due consideration in the design of septic tank covers.

Scum Formation. The formation of a permanent scum has been noted on the septic tanks at Ashland, Delaware, East Cleveland, Sandusky Soldiers' and Sailors' Home, Marion, Trumbull County Infirmary Warren, and Westerville. The probability of permanent natural scum covering cannot usually be predicted from general considerations, but according to evidence available from this investigation, the tendency to form a scum is largely determined by the relative quantity of actual sewage and ground and storm water. In the above cases, with the possible exception of Ashland, the sewage is strong, or in other words, the quantity of organic matter is large compared with the volume of water with which it is mixed. In the larger plants of the state, particularly at Mansfield and Lakewood, where the sewage is ordinarily dilute and contains appreciable quantities of dissolved oxygen and nitrates, no permanent scum forms. At Marion, where the sewage is perhaps as strong as that of any other municipal sewage in Ohio, there was some evidence of permanent scum formation when there was a direct flow from the grit chambers into the septic tank nearest the inlet. When, however, there was used a greater length of grit chamber, a feature which afforded an opportunity for the disintegration of the coarser excrementitious matters, even during the first 15 feet of travel in the septic tank practically no permanent scum has been noted.

Aeration and Odors. In the earlier septic tank installations (Mansfield, Lakewood and Sandusky Soldiers' and Sailors' Home) provision was made for aerating the septic sewage in order to remove gases and other products of anaerobic bacterial activity which are incidental to the passage of sewage through a septic tank. By this means it was supposed that the septic effluent would be more amenable to subsequent purification. Present knowledge, however, of the function of the so-called septic tank largely brought about by the evidence obtained from the Columbus experiments, has shown that the tanks exert but little influence upon the character of the liquid portion of the sewage, provided, of course, the period of flow is not too prolonged and that their real function is the removal of a part of the suspended matters and the partial hydrolysis of the deposited sludge. The aeration of septic sewage as shown by the results at Mansfield and Lakewood, introduces but a small percentage of dissolved oxygen and so far as can be judged by the results of this investigation, this feature does not materially improve nor otherwise effect the purification of the septic effluent. In none of the Ohio septic tanks, even those in which the period of flow is 24 hours or longer has there been found any evidence of over-septicization, that is, the effluents from these tanks aside from the inconvenience caused by the occasional presence of excessive quantities of suspended matters have not been more difficult to oxidize than those from tanks with shorter periods of flow.

The aeration of the septic effluent, moreover, means the loss of some head and also tends to create an unnecessary nuisance from odors, especially in the case of a strong sewage. Experience at the Soldiers' and Sailors' Home Sandusky, are a case in point where it was found necessary to remove the aerating devices since in certain seasons the odor therefrom was very obnoxious. There is also another objection to aeration of septic sewage especially under winter conditions, that is, the loss in temperature. The cooling of the sewage may be a matter of only a few degrees, as at Mansfield or Lakewood, or as great as 17 degrees F. as was the case at Sandusky Soldiers' and Sailors' Home, where the initial temperature of the sewage is quite high.

Summarizing the evidence as to the question of aeration, this investigation has indicated that there is no special benefit as regards the subsequent purification of the sewage in oxidizing devices, that there may be a decidedly unnecessary nuisance from odors and that there is at times a needless loss in temperature which may seriously interfere with the finishing devices during winter weather.

Odors have not been especially pronounced near septic tanks, and at distances greater than from 100 to 200 feet, in none of the plants studied has there been any cause for criticism in this regard. It appears also that odors from septic tanks so operated arise chiefly from the scum, and that under proper operation but little objectionable conditions can be traced to the effluent of the tank itself.

Dissolved Oxygen in Septic Effluents. One of the points raised by the claimants for patents on the use of the septic tank, is the establishment of anaerobic conditions within the tank by the passage of sewage through the same with the exclusion of air and light and with a minimum of disturbance of inflow and of outflow, respectively. Importance is placed by the claimant upon the necessity for a complete absence of dissolved oxygen in order that there shall be the most favorable conditions for the development of anaerobic bacteria.

During this investigation, there were collected a number of samples of septic effluents for the determination of dissolved oxygen. Of the 19 septic tanks studied, the effluents from these tanks were found to contain dissolved oxygen in 8 instances or in 42 per cent. of the septic tanks in operation in the state, and notably at Ashland, Delaware, Geneva, Kenton, Lakewood, Mansfield and Plain City dissolved oxygen is ordinarily present, except perhaps when the tanks are receiving the strongest sewage in the morning hours. The quantity of dissolved oxygen in the septic effluents in Ohio ranged from 0.0 to 5.0 parts per million. Leading results as to the dissolved oxygen in the effluents of representative Ohio septic tanks are shown in the next table. It is important to state that so far as may be judged from the data available from this investigation, the presence of dissolved oxygen has not in any way influenced the efficiency of the tanks as a preparatory treatment for a removal of a part of the suspended matter in the crude sewage. As previously discussed, moreover, practically none of the effluents from the septic tanks in Ohio appear to be so modified by their passage through the tanks as to influence their subsequent treatment on oxidizing devices, except as regards the quantity of suspended matters and their relation to clogging. So far as these data are concerned, the action of Ohio septic tanks in the resolution of sludge and in the preparatory treatment of the sewage has not been appreciably affected nor influenced by the presence of aerobic conditions within the tanks. It seems plausible to suggest, moreover, that bacterial activities in septic tanks are not exclusively attributable to the development of obligate anaerobes, but are also the work of facilitative aerobes.

The above is of note in view of practically a contrary assertion on the part of the claimant for a patent on the septic process of sewage treatment.

TABLE NO. 101.

Dissolved Oxygen in the Applied Sewages and in the Effluents of Representative Septic Tanks in Ohio.

Place.	Date of Examination.	Temp. Degrees F.		Dissolved Oxygen.											
				Parts per Million.						Per. Cent. Saturation.					
				Maximum.		Minimum.		Average.		Maximum.		Minimum.		Average.	
		Sewage.	Effluent.	Sew.	Eff.	Sew.	Eff.	Sew.	Eff.	Sew.	Eff.	Sew.	Eff.	Sew.	Eff.
Ashland	July 11-12, 1906	60	61	3.2	0.0	0.0	0.0	0.7	0.0	31	0	0	0	7	0
Ashland	April 24-25, 1907	47	47	4.3	4.9	1.7	0.0	3.1	3.3	37	42	14	0	26	28
Delaware	May 8-9, 1907	52	52	2.2	1.5	0.4	0.0	1.3	0.4	20	14	4	0	12	4
East Cleveland	June 26-27, 1906	60	59	0.2	0.0	0.0	0.0	0.1	0.0	2	0	0	0	1	0
East Cleveland	July 11-12, 1907	60	60	0.2	0.0	0.0	0.0	0.1	0.0	2	0	0	0	1	0
Geneva	June 24-25, 1907	56	57	3.3	2.0	1.6	1.4	2.2	1.7	31	19	15	13	21	16
Kenton	July 2-3, 1907	64	63	3.9	1.6	2.7	0.0	3.5	0.9	41	16	28	0	36	9
Lakewood	June 12-14, 1907	53	54	6.1	.....	2.2	.....	5.2	4.5	56	.....	20	.....	48	42
Mansfield	July 25-26, 1906	64	66	2.3	1.8	0.0	0.0	0.6	0.5	24	19	0	0	6	5
Mansfield	May 28-29, 1907	57	55	7.1	1.5	0.3	0.0	2.4	0.8	68	14	3	0	23	8
Marion	May 23-25, 1906	50	51	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
Marion	Nov. 7-9, 1906	59	58	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
Plain City	Aug. 1-2, 1906	58	59	7.0	6.2	4.2	4.4	5.0	5.1	68	61	41	43	50	50
Sandusky, S. & S. Home	May 8-9, 1907	65	68	1.4	0.0	0.0	0.0	0.9	0.0	15	0	0	0	9	0

NOTE. — Results cover periods of 24 or 48 hours as indicated; samples collected at four-hour intervals.

Efficiency. This investigation has shown widely differing efficiencies in the septic tanks in operation in Ohio, due to a large number of different causes, the most important of which perhaps is the lack of flexibility, that is, the impracticability of varying the rate of flow through the tank, or the total tank capacity in service. So far as may be inferred from the results of the detailed examinations, with very few exceptions, there was a negative removal of suspended matter, or in other words large quantities of finely divided material are frequently carried out of the tank with the effluent. The results in this regard are shown in the next table. It is to be noted that these data represent the analyses of average samples of the crude sewage for a period of 24 or 48 hours, and as well average samples of the effluent of the septic tanks for similar periods with due allowance for the average time the passage of sewage through the tanks. Furthermore, the data represent chiefly dry weather conditions and cover periods from early spring to late fall. In all these cases, of course, there are periods during which sludge accumulates in the tanks and at such times the effluent contains much less suspended matter than the applied sewage. Moreover, it may be merely a coincidence that these examinations happened to be made at such times when bacterial activities in the tanks were especially pronounced.

TABLE NO. 102.

Suspended Matter in Effluents of Representative Ohio Septic Tanks.

Place.	Date 1906-07.	Rate of Sewage Flow Gals. in 24 Hours.	Hours Flow.	Suspended Matter. Parts per Million. Crude Sewage.	Septic Sewage.	Percentage Removal.
Ashland	July 11-12, 1906...	150,000	6.3	70	50	29
Ashland	April 24-25, 1907..	375,000	2.5	50	70	—40
East. Cleveland...	June 26-27, 1906..	365,000	11.2	210	400	—91
East. Cleveland...	July 11-12, 1907...	390,000	10.4	110	180	—64
Geneva	June 21-22, 1906..	181,000	5.2	60	65	— 8
Geneva	June 24-25, 1907..	204,000	4.6	90	150	—67
Kenton, N. Dist..	Octo'ber 5, 1906...	18,000	24	220	180	18
Kenton, N. Dist..	July 2-3, 1907.....	17,000	27	70	120	—72
Lakewood	June 12-14, 1906..	395,000	18	45	45	0
Lakewood	June 12-14, 1907..	1,150,000	6.2	100	140	—40
Mansfield	May 28-29, 1907...	1,058,000	23	75	110	—47
Marion	May 23-25, 1906...	415,000	24	150	85	43
Marion	Nov. 8-9, 1906....	370,000	27	90	140	—55
Marion	April 9-11, 1907..	578,000	17	40	45	—12
Sandusky, S. & S. Home	June 5-6, 1906.....	155,000	17	95	90	5
Sandusky, S. & S. Home	May 8-9,1907.....	174,000	15	95	90	5

NOTE. Suspended matter to nearest 5 parts below 100 and to nearest 10 parts above 100.

The evidence just presented suggests that the removal of suspended matter in these septic tanks, practically all of which are single tanks, is at times by no

means so great as recent experimental evidence[1] indicates to be possible under proper regulation and with due attention to operation. The lack of flexibility and the poor results which have been obtained from these single compartment tanks strongly indicates that instead of a single compartment, which contains perhaps an inlet and an outlet baffle, there should be a series of compartments so arranged that the sewage may be caused to flow into the tanks in turn, and that further the number of tanks in service may be varied at the will of the operator.

In many of the tanks studied during this investigation there is little or no opportunity for flexibility in operation, and at times, a greatly increased volume of sewage flow causes suspended matters originally deposited near the inlet, due to a higher linear velocity, to be carried near the outlet. Frequently, also, large masses of this material are suddenly forced to the surface of the sewage by the gases of decomposition and pass out with the effluent. In 8 of the 19 septic tanks in operation, periods of violent sludge movements are very pronounced and in practically all of these cases there is then produced an effluent which contains two or three times as much suspended matter as is present in the average sewage. (See especially Marion, Mansfield and East Cleveland.)

It is of course, understood that the inlets and outlets of the septic tanks should be so arranged as to admit of as little disturbance as possible and also to effect the distribution of the incoming sewage over the greater part of the cross sectional area of the tank. The inlets of the Ohio septic tanks show great variation in detail of construction, among which may be mentioned weirs, iron pipe, branched and provided with ordinary gate valves, and elbows extending from a common inlet channel to a point perhaps one-fourth of the depth of the tank. There has been considerable difficulty in operating some of the septic tanks on account of the clogging of the inlets. This was especially pronounced at Sandusky Soldiers' and Sailors' Home, where the flow through the tanks is controlled by an ordinary gate valve. The paper, rags and burnt matches in this strong institutional sewage have frequently clogged the gate valves and have thus seriously interfered with the proper operation of the tanks. Weirs appear to be the most free from objectionable clogging. At a number of plants (Delaware, London, Plain City and Westerville) the inlets comprise elbows in the common inlet channel, and are subject to frequent clogging with the result that the tank nearest the main sewer receives the greater part of the sewage flow.

Similar points may be raised with reference to the construction of outlets. At two of the plants, namely Lakewood and Mansfield, the outlets comprise a series of 2-inch wrought iron pipes, 12 inches center to center and 6 inches apart vertically. These outlets discharge into a shallow concrete channel and in the case of Mansfield, the invert of the lower row of outlet pipes is so close to the bottom of the channel that sludge voided from the septic tanks gradually accumulates and during recent years has caused considerable trouble by stopping up the outlets.

Facilities for Measurement of Flow.

Another point suggests itself with reference to the design of septic tanks or other devices for preparatory treatment, namely a provision for measuring the sewage flow. Gaging of the quantity of sewage, of course, forms an important part of a detailed examination and in a majority of instances, it is necessary to construct temporary weirs for this purpose.

At Mansfield, the weir is placed at the head of the aerating channel. This is the only instance in the septic tanks examined of permanent means for gaging the sewage flow. It is perhaps better practice, whenever possible, to arrange for

[1] Columbus, Ohio. Report of Sewage Purification, G. A. Johnson.

gaging the sewage flow after the sewage has received a preparatory treatment on account of the interference of sludge and the fouling of the weir plate when the weir is placed at the inlet end of the tank.

The desirability of means for weiring the sewage flow is being recognized for all plants whether they contain septic tanks or not. For example at the recently constructed plant at the Massillon State Hospital, a small weir chamber and weir is provided at the entrance to the dosing tank. Although some interference from suspended matter is to be expected, where the untreated sewage is weired, yet the measurements are no doubt sufficiently accurate for ordinary practical purposes. To facilitate the work of inspection and examination and to advance general knowledge of the operation of sewage purification plants, it is highly desirable that permanent facilities be provided for gaging the sewage flow in all sewage purification plants.

Advantages of Secondary Sedimentation.

The clogging of the outlets of septic tanks and the prejudicial effect of voided suspended matters and sludge upon the finishing devices which follow sedimentation in septic tanks, suggests the desirability of a practical method for the removal of the abnormal quantities of suspended matter which are visible in the effluents of single compartment septic tanks at certain seasons of the year. It is not intended to discuss in full all measures which have been proposed for this purpose, but it is the desire to call attention to the fact that at Marion a small part of the surface area of each contact filter has been set apart to receive the applied septic sewage. These small basins, or grips in the filtering material, which afford only a brief period of retention, serve materially to arrest the greater part of the black suspended particles in the septic effluent and thus are a decided protection to the main body of the filtering material. Evidence at Marion and Mansfield suggests that the suspended matters in the septic effluents admit of rapid subsidence under even a short path of travel so that a tank with a capacity of only two hours' flow can be made of benefit as a supplement to the main portion of the preparatory process. The adoption of such means for improving the general average character of the septic effluent is suggested more as a method of obtaining higher efficiencies of those plants which are non-flexible and which are composed of a single compartment and with but limited baffling, for it is to overcome the objectionable conditions which are brought about by excessive gas formation in the septic sludge, that the elastic and flexible design of the septic tank has been proposed. Such is the design of the 8-½ million gallon septic tanks at Columbus, and such appears to be the tendency of the most modern plants in which sedimentation in septic tanks comprises the principal preparatory treatment of the crude sewage. It is further important to note that these small tanks suggested for the secondary sedimentation of the septic effluent are intended to intercept the finely divided suspended matters which are periodically discharged with the effluent of the septic tanks. In most instances this material is thoroughly digested and is no longer amenable to bacterial action and hence has lost its power of fomenting. Sludge of this character is expected in the last compartment of the large septic tanks at Columbus, Ohio, and from the experimental evidence there obtained it is probable that this section of the tanks will require very infrequent cleaning.

Disposal of Septic Sludge.

Interesting information was obtained at Ashland, East Cleveland, Mansfield, Plain City, Shelby and Westerville as to the problem of the disposal of septic sludge and the degree of inconvenience and nuisance from odors that such a process entails. In common with the results obtained in the Columbus experi-

ments, Mansfield experiences which have already been reviewed at length, indicate that the removal and disposal of well digested sludge from a septic tank is not an objectionable undertaking and does not possess so many disagreeable features as might at first be supposed. Sludge disposal at Mansfield was carried out without unusual difficulties and with practically no attendant odors.

Following the cleaning of the septic tanks at Mansfield, similar work was carried out at Plain City and Westerville, and in both cases there was little nuisance from odor. Provided sufficient time is allowed for a partial digestion of the sludge there appears to be no special difficulties attending its disposal. The sludge is inky black in color and is generally homogeneous and granular, and when allowed to dry, rapidly oxidizes and leaves a residue which is closely allied to humus matter. At Mansfield, the sludge was in part allowed to flow through the sludge valves into the adjacent stream, and was in part removed with buckets. At Plain City and Westerville, the sludge was shoveled into buckets since its density was so great that the ordinary contractor's diaphram pump there employed could not be successfully used. It appears, however, that a centrifugal or a dredge pump may be used for this purpose.

Sludge was removed from the septic tank at East Cleveland five times during its seven years of operation. The method there employed was the removal of the mixed sludge and supernatant sewage by means of a steam siphon which comprised a ½-inch steam jet and several feet of 4-inch pipe. The sludge forced from the tank was deposited in shallow excavations and after a short period of subsidence the liquid portion was allowed to flow away. To overcome any possible objectionable odors, common quicklime was spread over the partially dried residue.

At Shelby, Ohio, where the septic tanks or sludge pits (as locally called), are cleaned at intervals of six months, a device is in use which appears to be very satisfactory for smaller plants. It comprises a bucket conveyor which is placed over the tank on a platform erected for that purpose and by which the sludge is raised by hand power and discharged through a trough into a tank wagon from which it is discharged in thin layers onto the surface of grassed land. The tanks at Shelby have a capacity of only 7,700 gallons and prior to the removal of sludge the entire contents of the tank are stirred with a pole. The density of the sludge is very low, and it therefore flows readily so that its disposal by gravity discharge from the tank wagon can readily be accomplished. This machine is operated by four men and a foreman.

The quantity of sludge to be removed from septic tanks cannot be accurately stated from the results of this investigation since there are so many factors with relation to the operation of the septic tanks in Ohio, which control the actual volume of sludge accumulation in the septic tanks. At Mansfield, the septic tanks were not cleaned until after four years use, and then not because the accumulations warranted such a step but because of the clogging of the outlet pipes as already discussed. At this plant particularly there has been a more or less constant discharge of sludge with the septic effluent. This feature is of special importance and is common to practically all of the septic tanks in Ohio. It is of special significance with respect to the frequent assertion that septic tanks are efficient in the destruction of large quantities of sludge. Such statements should be viewed with caution, since especially in the older designs where there is no flexibility and but little baffling, large quantities of suspended matters escape with the effluents to the detriment of the purification devices which follow. At Ashland it is the practice to clean the septic tanks three to four times each year. At Shelby, the small tanks are cleaned twice each year, and in the case of Plain City and Westerville, the cleaning suggested in 1906 was the first since they were placed in service. Of the 19 septic tanks in operation, five were cleaned during

this investigation, four required cleaning at its close and the remainder have as yet never been cleaned. While it is somewhat difficult to state the frequency of the obligatory removals of sludge from settling or septic tanks, based on the general information derived from the Columbus experiments, as to an accumulating average of about 3 cubic yards per million gallons from an actual deposit of 6 cubic yards per million gallons, it is possible to design a floor area sufficient to permit of the storage of sludge for periods of from 6 to 8 months.

For the disposal of sludge from the septic tank, a feature which appears to be a necessity for all plants although the exact frequency cannot generally be predicted, it seems desirable to arrange for a suitably underdrained filter for its reception, so that the liquid portion may be drained off as soon as possible and thus hasten the oxidation of the solid residue. Coarse sand, fine cinders, coke or ashes can probably be used to advantage in the construction of sludge filters. In the absence of such provisions in the design of the plant, at Mansfield the sludge was used as a fill and at the other two places mentioned, shallow trenches, perhaps 6 inches deep and 3 feet or more wide, were prepared for its reception.

The cost of sludge disposal at Mansfield was about 50 cents per cubic yard and at Plain City was about $1.00. In the latter plant the operation was on a very small scale and no doubt there were a number of features which combined to increase the cost. When performed as an occasionally routine as in the larger and more modern plants according to experiences at Birmingham, England, sludge disposal may be carried out for only about five cents per cubic yard. At Birmingham, the entire operation is performed by gravity, and there is but little manual labor entailed.

PURIFICATION ON FILTERS OF FINE GRAIN MATERIAL.

In this section are discussed those types of finishing treatment in which the filtering material is natural soil, sand, fine coke or crushed cinders. For convenience they are classed under the head of purification by filters of fine grain material. The use of sand filters in the purification of sewage under Ohio conditions is confined to the smaller municipalities and to the institutions, in view of the fact that large areas of sandy soil of proper character are not usually available and because the cost of suitable sand artificially placed is such as to render its use prohibitive except in small scale plants. Of the eight municipal plants where filters of fine grain material are operated, six comprise underdrained areas of natural soil, one fine cinders, and one lake or bank sand or fine gravel. At the institutions where such filters are used, for the greater part they are constructed of sand obtained from some distance. One plant contains fine coke breeze (Trumbull County Infirmary).

Desirability of Intermittent Operation and the Application of Sewage in Doses.

Early in the investigation it was developed that a number of the sand filter plants were inefficient in view of the fact that their operation was on a continuous basis and that there was too small appreciation of the principles which underly the successful operation of sand filters, that is, the necessity for the intermittent application of sewage and the desirability of flooding the filters in doses. In the case of the municipal plants, low efficiency was found at Ashland, Clyde, Geneva and Shelby, and in the institutional plants at Mansfield State Reformatory and at the State Institution for Feeble Minded Youth at Morgans. In practically all of these cases decided improvement was effected by greater attention to intermittent operation.

Especially true of smaller municipalities and institutions, the successful operation of sand filters for sewage relates to the method of flooding. The filters should be used in strict rotation and the sewage be applied in doses in order that periods of rest may be afforded. This point is especially in evidence at the Lancaster Boys' Industrial School where there are no dosing devices. The rate of sewage flow at these institutions and in general at the smaller plants is so low that it is not practicable efficiently to flood a comparatively large filter area unless the sewage may be stored until there has accumulated a dose of sufficient volume. Poor distribution and low resulting efficiency suggest that a dosing tank should usually be included in the design of a sewage purification plant for small communities and for institutions.

Method of Distribution.

The distribution of the sewage onto the surface of sand filters is generally accomplished by some form of trough distributor constructed of wood, or by half-tile with loosely laid or notched joints, or in case of some of the larger units, by heaps of stones or concrete slabs placed at the point of discharge of the main influent carrier. Wooden or concrete slabs are also provided at the discharge of the several branches of the surface distributors. Information available from this investigation suggests that from four to five years is the ordinary life of wooden trough distributors under practical operating conditions.

As to the number of points of discharge and the area covered by the distributors, there is a decided variance in the different plants in Ohio. In some places there is provided one single line of half-tile extending to the center of a unit (Montgomery Co. Infirmary), or more commonly found extensively branched wooden carriers which have five or more points of discharge. When there is a direct flow of sewage onto the filters, it is probable that it is advantageous to provide for as thorough a distribution as possible, but in case the sewage is applied in a large dose, or by pumping, there is apparently little need for an extended system of surface distributors. For example, at Fostoria where pumping is employed, there are no surface distributors and at Fairmount Children's Home, Gallipolis State Epileptic Hospital, Mansfield State Reformatory, and at several of the smaller plants, one non-branched distributor is all that is used and the large volume of sewage applied at one time is satisfactorily distributed over the entire area of the filter.

It is not the general practice to fasten or anchor distributors to the filter, but in case wooden distributors are used in places where the dose of sewage is sufficient to float the troughs, it is necessary to anchor them in order that they will remain in a proper position.

Automatic Dosing Devices.

One of the municipal plants and ten of the institutional plants are provided with devices for applying the sewage in doses, an arrangement which entails the use of siphons or other apparatus for causing the dosing feature to be essentially automatic in character. The greater number of plants with dosing devices (nine) are provided with single siphons. In one instance, (Fairmount Children's Home) alternating siphons are used, at Geneva six plural alternating siphons are in operation in conjunction with the pumping plant and at two of the institutions (Massillon State Hospital and Soldiers' and Sailors' Home, Sandusky) in addition to the single 10-inch siphons, an apparatus is in use for diverting the sewage successively to four sets of filters. All of the single, double and plural siphonic apparatus has been found to operate satisfactory, provided it receives occasional supervision, or in other words the ordinary oversight necessary for the proper maintenance of all machinery.

Attention Required by Surface Material.

In a majority of the plants examined there is no systematic cleaning of the surface material and removal of clogged sand, and in no case is the information sufficiently reliable so that these operating data with regard to the removal of filtering material may be stated in terms of the volume of sewage treated. In some of the institutional plants, Montgomery County Infirmary, Mansfield State Reformatory, Soldiers' and Sailors' Home and Fairmount Children's Home in particular, a considerable quantity of sand has been removed since the plants were first operated and in both of these cases a renewal of the sand has been necessary. In most of the plants it is the general practice to plow and rake the filters twice each year, but to remove vegetation at more frequent intervals during the summer months. In some of the plants examined, but little difficulty has been experienced in maintaining the filters in a porous condition, provided the operation of the plant is strictly intermittent so that there is ample opportunity for the beneficial effect of air and sunlight causing the deposits to dry and peel.

Of special interest are the experiences at Clyde where the filters are operated continuously, that is, on a water filter basis (slow sand filtration). At this plant the sewage is exceedingly dilute and is well oxygenated and on this account there appears to be no difficulty in securing aerobic conditions and a fairly satisfactory degree of purification throughout the year. Besides this unusual instance of the successful operation of sewage filters continuously, it has not been found necessary to clean the filters more than once or twice each year and at such times it has not been necessary to remove the suspended solid matter. The suspended matters in the Clyde sewage, as already mentioned, are granular and appear to permit of the ready passage of sewage. Cleaning is accomplished by plowing, harrowing and leveling and the accumulated deposit is turned in in a manner similar to that employed in the cultivation of farm land.

At some of the institutional plants, the filters are scraped at very frequent intervals and the coating of suspended matters is entirely removed. In common with New England experiences the character of the preparatory treatment influences the general nature of the suspended matter, the degree of penetration and the extent of the clogging and the actual removal of filtering material. In the absence of preparatory treatment, the suspended matters carried by the applied sewage are coarse and readily form a mat (Montgomery County Infirmary, Boys' Industrial School, Lancaster), which protects the main body of the filtering material and prevents the entrance of the finer suspended particles into the sub-surface depths. The effluents from chemical precipitation (Glenville), and from septic tanks, however, contain suspended matter of a gelatinous nature and so finely divided as readily to penetrate beneath the surface of the sand and at times to a considerable depth. Under such conditions, there is eventually necessary a complete removal of the upper layers of the filtering material. Such has been especially the case at the Soldiers' and Sailors' Home Sandusky. These experiences further emphasize the desirability of a thoroughly settled septic effluent when used in conjunction with sand filters in order that there may be a minimum of clogging and the least possible obligatory removal of the filtering material.

Surface clogging due to algal growths was experienced at Mansfield State Reformatory and similarly to results obtained at Pawtucket, Rhode Island [1], the use of copper sulphate at a concentration of about 10 parts per million furnished a satisfactory means for eradicating these troublesome growths and for restoring the filters to serviceable condition.

[1] Monthly Bulletin, Rhode Island State Board of Health, Vol. XVIII, No. 11-12; Vol. XIX, No. 3.

Furrows Versus Flat Surfaces Under Winter Conditions.

Conditions in Ohio during the colder months of the year are such that in the larger plants but little difficulty is experienced in their operation. Since most of the fine grain plants are at institutions where the temperature of the sewage is fairly high it is not necessary to furrow the filters in order that they may successfully be operated during the winter months. Furrows, however, have been used at Gallipolis State Epileptic Hospital, Soldiers' and Sailors' Home Sandusky, and Toledo State Hospital.

Availability of Filtering Material.

Ohio conditions are such that considerable areas of gravel, sand or porous soil are rarely found on sites available for sewage purification. However, in a few municipal plants, questions of cost necessitate the use of land often composed of loam or clayey soil, a somewhat poor material for the purpose. Plants of this type are those at Ashland, Clyde, Fostoria, Glenville, Oberlin, Shelby and Xenia. In institutions similar conditions are found at Denison University, Morgans State Institution for Feeble Minded Youth and Toledo State Hospital. The effective size of the soil in these plants ranges from 0.03, fine clay (Clyde), to 1.10 m. m. fine gravel (Fostoria).

The plant at Geneva is the only municipal plant constructed of sand artifically placed. The filters at a majority of the institutions where purification is effected by filters of fine grain material are constructed of bank or lake sand, crushed sandstone or fine cinders. Data in this regard are shown in the next table.

Sub-surface Irrigation.

At least two sub-surface irrigation plants have been operated in Ohio, namely at the Hardin County Infirmary and at the Fairmount Children's Home, Alliance. Both of these plants were failures on account of the poor quality of the soil. Plants of this type are usually successful only where areas of sandy soil are available and these two experiences indicate that for Ohio conditions a sub-surface irrigation plant is rarely a success, except for small residential installations where suitable sandy soil can sometimes be obtained.

Rates of Treatment.

The rates of operation of the sand filters in Ohio vary widely, depending upon the character of the filtering material and the extent to which the sewage is clarified before final treatment. In the next table are shown the average rates of filtration, the population load per acre, the extent of the preparatory treatmen and the general efficiency of all of the sand filter plants examined. Rates of treatment range from 17,500 to 1,200,000 gallons per acre daily and it is evident that preparatory treatment broadly speaking, makes possible about double the rate where crude sewage is applied to the filters.

The population loads which are perhaps the best basis for design show a range from 250 to 2,650 for no preliminary treatment and from 600 to 14,500 when a preparatory process is employed. Certain anomalies appear in the table and are perhaps explained by uncertainties in the data as to the population served. However, available information indicates that to insure good results in actual practice the application of crude sewage to sand filters constructed of a good quality of bank or lake sand, the population load per acre should not be greater than from 500 to 600; when preceded by sedimentation in settling or septic tanks the load may be increased to from 1,000 to 1,200.

TABLE NO. 103.

Rates of Filtration and General Data of Fine Grain Filters in Ohio.

Place.	Preparatory Treatment.	Filtering Material.		Rate of Filtration, Gallons per Acre in 24 Hours.	Population per Acre.	General Efficiency.
		Kind.	Eff. size m. m.			
Municipal						
Ashland	Septic tanks	Sandy gravel	0.24	68,000	600	Good
Clyde	None	Clayey sand	0.03	110,000	390	Good
Fostoria	None	Clayey sand	0.12 to 1.10	17,500	250	Good
Geneva	Septic tanks	Sand	0.35	292,000	1,940	Good
Glenville	Chemical precipitation and strainers	Sand	0.09	1,200,000	6,500	Poor
Marion	Septic tanks and contact filters.	Sand and limestone screenings	0.35 0.80	590,000	14,500	Good
Oberlin	Chemical precipitation	Loam	0.09	48,000	650	Fair
Shelby	Sludge pits and reservoirs	Cinders	0.24	418,000	2,800	Good
Xenia	Sludge pits	Gravel	Fine	Out of service		Poor
Institutional.						
Fairmount Children's Home	None	Bank sand	0.20	65,000	650	Good
Montgomery Counnty Infirmary	None	Bank sand	0.24	20,000±	530	Fair
Gallia County Infirmary	None	Bank sand	Medium	23,000	570	Good
Gallipolis State Epileptic Hospital, Main Buildings	None	Bank sand	0.30	89,000	725	Good
Gallipolis State Epileptic Hospital, Cottage I	None	Bank sand	0.28	110,000	865	Good
Denison University, Granville	None	Bank sand	Fine		550	Good
Lancaster Boys' Industrial School	None	Crushed sandstone	0.21	32,000	575	Good
Mansfield State Reformatory	None	Crushed sandstone	0.22	62,000	745	Fair

Massillon State Hospital	None	Sandy soil	0.24 to 0.45	73,000	533	Good
Ohio Institution for Feeble Minded Youth, Morgans	None	Sand	Coarse	47,000	2,650	Poor
Sandusky Soldiers' and Sailors' Home	Septic tanks	Lake sand	0.28	170,000	1,125	Good
Toledo State Hospital	None	Natural soil	0.03	60,000	290	Good
Trumbull Co. Infirmary	Septic tanks	Fine coke	1/16 to 1/4 inch	83,000	2,200	Good
Warrensville Cleve. Tuberculosis Farm Colony	Septic tanks	Sand	Medium	70,000	1,175	Fair
Wayne County Children's Home.	None	Bank sand	0.15	17,500	833	Good

Cropping.

At the Main Building's plant at the Gallipolis State Epileptic Hospital the filters are cropped with corn and one successful crop is raised each year. At the Toledo State Hospital certain of the filters were formerly cultivated each year, but the practice was discontinued in 1907. At Fostoria also, a crop of corn is raised each year on a part of the plant. While there is no direct evidence from these Ohio experiences that cropping is prejudicial to the life of sand filters in that it tends to reduce the size of the surface filtering material, yet the practice of growing crops on sewage plants has not been encouraged since when devoted to the raising of crops, the operation of the sewage filters generally becomes of secondary importance.

Construction of Underdrains.

Experiences at the Boys' Industrial School Lancaster, Glenville and Mansfield State Reformatory indicate that it is very essential to provide for the proper protection of the underdrains in fine grain filters from clogging due to the penetration of the fine filtering material into the joints. While in the majority of the plants coarse gravel layers are placed around the underdrains and these in turn covered by a graded layer of gravel extending upward perhaps for several inches, yet in some instances no attention is paid to this important feature and somewhat low efficiency is obtained in regard to the draining of the sewage from the sand. Aside from providing a sufficient slope on the lateral and main underdrains, it is highly desirable that the drains be suitably protected by coarse material and that there shall be a free flow so that ample opportunity will be afforded for the aeration of the sand.

Protection of Embankments by Seeding.

At the recently constructed plant at the Massillon State Hospital, considerable annoyance was experienced by clay washing onto the filtering material during rains. Similar trouble was experienced at London in the construction of the contact filters. In neither of these cases were there provisions in the contract for seeding the embankments. These experiences suggest the importance of requiring the seeding of embankments surrounding newly constructed sewage purification plants at the earliest opportunity in order that rains may not seriously impair the filters by causing mud and clay to be carried onto the filtering material. In most cases, of course, after sometime there develops a more or less luxuriant growth of vegetation which then serves the same purpose as seeding.

Efficiency.

As stated in the preceding table, the general efficiency of the fine grain filters in Ohio is satisfactory, that is, the plants have abated or prevented a local nuisance and have satisfied the conditions for which they were installed. While the effluents from these filters are perhaps more highly purified than are those from the other types of sewage filters in operation in the state, yet there is a decided range in the actual degree of chemical purity exhibited by the several effluents. Nonputrescible, fairly clear effluents are the rule and in some instances (Fairmount Children's Home, Trumbull County Infirmary, Gallipolis State Epileptic Main Buildings' Plant, and Soldiers' and Sailors' Home Sandusky), strong nitrification is in evidence. The lower nitrification in the majority of the effluents is perhaps in part due to the weakness of the crude sewage. With few exceptions, the brilliant, odorless effluent of the most efficient sand filter under optimum operating

conditions is rarely found in practice in the Ohio plants, but the results actually obtained are such as to admit of but little criticism from a practical standpoint. The poor effluents at the Mansfield State Reformatory and the Montgomery County Infirmary are attributable to the reduced layer of fine grain filtering material and the poor results at the Institution for Feeble Minded Youth at Morgans are due to a lack of sufficient area.

All of these conditions had been or were to be remedied at the close of the investigation. In general, a study of the analytical data will show an improvement in the character of the results obtained by the fine grain filters examined as the investigation progressed, owing to changes in operating procedures or in construction in most instances from suggestions made by the State Board of Health.

PURIFICATION ON FILTERS OF COARSE GRAIN MATERIAL.

While a majority of the sewage filters investigated are constructed of fine grain material, there were eight plants examined in which the filtering material is coarse, and in these the sewage is purified by the contact plan, or by methods of continuous filtration. No sprinkling filters were in operation during the investigation, although in the most recent designs, notably Columbus, there is a tendency towards filters of this type. Filters on the contact plan are those at Lakewood, Mansfield, Marion and Lake Shore and Michigan Railroad Shops at Collinwood. One deep continuous filter is in operation at the Ohio Quarries Company, North Amherst, and shallow filters operated continuously, but originally planned as contact filters, are to be found at Delaware, Plain City, Westerville and London.

Contact Filters.

The plants at Lakewood and Mansfield are excellent examples of the fill-and-draw process of sewage treatment and at these places one single contact following sedimentation in septic tanks is sufficient to produce a non-putrescible effluent. In both of these instances automatic devices are in use for flooding and discharging the filters. The rate of filtration at these two plants is 800,000 gallons per acre (4 feet and 4 feet 9 inches deep, respectively), in 24 hours and the respective population load per acre is 11,200 and 9,600, or 2,240 and 2,000 per acre-foot. At both Lakewood and Mansfield the applied sewages are dilute and at times contain some dissolved oxygen and this fact may in part explain the uniformly satisfactory results which have been accomplished. At Marion the contact filters are operated by hand during the day time. Evidence obtained during this investigation shows that the single contact there practiced has not been sufficient to afford a non-putrescible effluent. During the night when the filters are operated continuously with open outlets, the effluent is decidedly unstable. The rate of operation at Marion is 590,000 gallons per acre in 24 hours and the population load per acre is 14,500 or 5,250 per acre-foot.

The small plant at the Lake Shore and Michigan Southern Railroad Shops at Collinwood, although operated automatically on the fill-and-draw plan, is not a true example of a contact filter, since the largely increased flow of sewage has interfered with the normal action of the filters. A number of interesting points were developed by a study of the Lakewood, Marion and Mansfield plants, especially with regard to features of operation. At Mansfield and Marion considerable difficulty has been experienced, due to surface clogging on account of the excessive quantities of finely divided suspended matter in the applied sewage. At Mansfield this feature has been especially pronounced and at Marion has brought about the construction of grips or shallow settling basins formed by setting apart a portion of the surface area of each filter, as already mentioned. These Marion experiences,

while showing the decided advantage of a secondary sedimentation of the septic sewage, also indicate that it is not essential to provide for the thorough distribution of sewage over a contact filter by means of branched carriers.

The clogging of the surface material in evidence particularly at these two plants suggests a decided loss in voids. Careful measurements made during this investigation showed a considerable reduction in open space at Mansfield, a small loss at Marion and but little at Lakewood. While the filters at Mansfield have sustained a considerable loss in capacity, due to the voiding of sludge from the septic tanks, yet it appears that there has been no tendency on the part of the cinder filtering material at either Lakewood or Mansfield to disintegrate, or noticeably to compact; neither does there appear to be any appreciable solvent action of the strong Marion sewage on the limestone filtering material in the contact filters. The results at Mansfield, Marion and Lakewood further suggest interesting points as to the process at work in a contact filter and indicate that a long period of rest is desirable as fostering the more rapid development of nitrification. In common with other experiences, except for the first contact after a period of rest, the effluents from the contact filters rarely contain material quantities of nitrogen as nitrates.

The beneficial effect of aeration and periods of rest in contact filters is, of course, well understood. In this connection it is of interest to note that at Marion, the outlet pipes are so located as to be sealed at all times by about 6 inches of sewage. At Lakewood and Mansfield, provisions are made to back flood the underdrains, but it is said the devices have never been used. In agreement with recent views on this matter,[1] available evidence indicates that it is better to provide for a complete draining of contact filters in order to obtain as free circulation of air as possible. In the case of Marion, the trapped outlets of the contact filters, of course, render the connection between the underdrains and the stack of the garbage crematory useless for aeration purposes.

The plants at Lakewood and Mansfield are operated entirely automatically with excellent results. The plant at Marion has been hand operated. There appears to be no objection to the hand operating plan, provided sufficient labor is available for proper attention to operating details.

Continuous Filters.

The plant at the Ohio Quarries Company, North Amherst, is the only example in the state of a deep continuous filter; this is constructed of 10 feet of crushed sandstone. The flow of sewage is too small for efficient distribution and on this account the effluent has been unsatisfactory. The distribution of the septic sewage onto the filtering material is accomplished by shallow troughs set horizontally resting on the filtering material proper, and placed at right angles to the main carrier, from which the sewage flows through 1-inch iron pipes. A study of this plant shows the impracticability of accomplishing a satisfactory distribution of a small volume of sewage through orifices on account of clogging and further, the difficulty of maintaining the proper alignment of horizontally placed troughs for the distribution of sewage. With a low sewage flow, evidence points strongly to the desirability of some method of dosing to insure satisfactory results.

Four of the plants where coarse grained filters are found, namely, Delaware, Plain City, Westerville and London, were originally planned for operation on the fill-and-draw basis. All of these plants are of similar design and contain 3 feet of crushed coke. Automatic apparatus is provided for filling the filters in rotation and for completing the usual cycles in the operation of contact filters. The automatic apparatus has failed to act positively and correctly and has neces-

[1] Venable, *Sewage Treatment*, 1908, pp. 85-89.

sitated the operation of the plant on a continuous basis. In spite of the very crude means for distribution there available, the continuous passage of the applied septic sewage through the 3 feet of cinder, results in a non-putrescible effluent. The effluent at Westerville is the least highly purified, but at that plant further treatment, on a secondary filter 6 feet in depth, suffices to produce a stable effluent. At Westerville in particular the plant receives little or no attention, and were it not for the fact that the crude sewage is weak, very unsatisfactory results would be obtained by the continuous method of operation there practiced. Considerable attention is given to the operation of the Plain City plant, but were it not for the dilute character of the crude sewage, the failure of the automatic apparatus would prevent the proper action of the filters in the treatment of the sewage. It is obviously very important that the automatic devices provided for the operation of sewage purification plants on the fill-and-draw basis should act positively and normally at all times. These experiences suggest that only well tried apparatus should be used, and that all devices of new or original design should be given thorough practical tests in order that their successful operation may be assured before they are installed in a practical plant.

Finishing Devices.

At Marion, is found the only example of a finishing treatment. The Marion filters are constructed mainly of limestone screenings which support a 3 to 6-inch layer of medium sand. They have been operated during the day hours only and at an average rate of 590,000 gallons per acre in 24 hours, corresponding to a population load per acre of 14,500. When operated, these finishing filters have produced a non-putrescible effluent and under Marion conditions are distinctly a necessary part of the treatment since the single contact filter effluent is generally unstable as shown by incubator tests.

Although it has not been necessary to remove clogged filtering material from these filters, yet such a removal would undoubtedly be necessary were they operated throughout the 24-hour period, as shown by the tendency to clog noted on the three 48-hour examinations during which the filters were operated continuously.

These Marion experiences suggest that high rate finishing filters are advantageous as a finishing treatment for coarse grain filters, and also that in the event of the non-availability of sand, the main portion of the filter may be constructed of coarse material without impairing the normal efficiency of filters of this type.

SUPERVISION AND MANAGEMENT.

One of the most striking points brought out by the investigation of the Ohio sewage purification plants is the close relation of supervision and efficiency and the failure of a number of the plants to afford a satisfactory purification of the sewage, mainly due to a tendency to neglect the plant and to pay little or no attention to its proper maintenance. Early in the investigation such conditions were found to be true in a number of plants which, owing to official indifference were either entirely out of service or were affording merely a rough clarification of the crude sewage.

Proper supervision means that one or more caretakers be appointed to operate the plant in order that there may be obtained the highest possible degree of purification corresponding to local conditions. Many plants have been constructed to abate or prevent a local nuisance from stream pollution, but the installation of devices for the purification of sewage does not solve the problem, since without the proper oversight very unsatisfactory results will be obtained until finally there is reached a condition where the neglected sewage plant causes

almost as great a nuisance as would be produced were the crude sewage discharged directly into the stream.

There is another phase of the problem which renders essential proper supervision and management, that is, the future necessity for the enlargement of the plant. In many sewage purification problems, on financial grounds there is first installed only a part of the plant considered by the engineer to be necessary to correspond to the future growth of the village. In order to effect an immediate improvement in a given set of conditions with respect to stream pollution, in a number of instances proposed plans for a partial temporary construction have been approved by the State Board of Health with the understanding that when necessary, the full complement of the design shall be provided. There are very few instances where enlargements of existing plans have been made and there appears to be a tendency to consider that the construction of even a small part of a sewage plant satisfactorily solves a given sewage purification problem for the present and also for future needs. It is clear that such a position is untenable. The necessary enlargement of the sewage plant, however, can be postponed if that part already constructed be carefully and faithfully operated for by this means factors of depreciation will be reduced and the devices in use may be successful in handling the increasing flow of sewage for a longer period than would otherwise be the case.

The labor necessary in the proper maintenance of sewage purification varies, of course, with the type of process represented. In filters constructed of sand, gravel or natural soil it is necessary to provide for the intermittent flooding of the several units and it is obligatory that the surfaces of the filters be maintained in a porous condition, that vegetation be not allowed to accumulate. Where automatic devices are used, it is essential that they receive care and attention in order that they may not be adversely effected by rust, or in other words they should receive such attention as is usually required by machinery. The operation of sewage plants in case automatic devices are used, of course, entails the least labor, especially in the smaller plants, and in such cases efficient operation may be obtained provided the plants are visited occasionally. In the larger plants, however, whether automatic devices are used or not, the study of practical conditions made during this investigation strongly indicates that permanent caretakers are essential and that their employment entails less expense in the long run. Such conditions are instanced in nineteen of the plants studied during this investigation.

It is unfortunate that there is frequently a tendency on the part of local officials to neglect the sewage purification plant, and unless their interest is aroused by the medium of an investigation of this character, sewage purification plants rapidly deteriorate and soon become practically useless. Such plants, of course, are not revenue producers and there is generally but little inducement offered for maintaining a high standard of efficiency. Frequently, there is exhibited an entire indifference to the fact that the sewage purification plant represents the expenditure of a certain amount of the public funds. As would be true of private undertakings, the plant should receive such intelligent supervision that the yearly depreciation may be reduced as much as possible.

The practical side of the advantages of the proper supervision and management of sewage purification plants is clearly brought out by the results which have been accomplished in Ohio during this investigation as described in the detailed reports. In fact, with few exceptions poor results at the plants studied are traceable entirely to neglect. One of the most important results of the investigation, the improvement of conditions existing in sewage purification plants is mainly due to an aroused interest on the part of local officials and this fact alone suggests the importance of proper methods of operation for the successful

solution of a local sewage problem subsequent to the construction of a sewage purification plant.

COSTS OF INSTALLATION.

As a basis of estimates, it is necessary to know approximately the cost of sewage purification plants of different types with respect to the number of persons for which a plant is to be designed. With this thought, the installation costs at the principal plants in Ohio are presented in the next table. In order to make these figures as comparable as possible, there has been taken as a basis that population which is estimated to correspond to the maximum capacity of the plant.

The first column of the table contains the present population of the city, village or institution; the second, the population tributary; the third, the estimated maximum population load; the fourth, the ratio between the maximum population load and the present number of persons tributary; the fifth, the cost of installation, and the sixth, the per capita cost based upon the figures in the third column. The plants are grouped according to the process represented as explained by side notes.

The great differences noticeable in these cost data are in part explained by the widely different conditions in the several plants, and the great variety of design, as will be clear from reference to the data tabulated at the close of this report. Of course, the availability of filtering materials near the site of the plant, is one of the large controlling factors of first cost after the type of plant has been decided upon.

From the detailed reports some idea may be formed of the unit costs of filters of different kinds. Local conditions so materially affect these figures that it is not thought advisable to present them in tabular form.

TABLE NO. 104.

Comparative Costs of Installation of Principal Ohio Sewage Purification Plants.

Place.	Estimated Population, 1907.	Estimated Population When Plant Was Installed.	Estimated Population, Tributary.	Estimated Population Corresponding to Total Capacity of Plant.	Ratio Present to Maximum Population Load.	Cost of Installation.	Cost Per Capita Based on Maximum Population Load.	Remarks.
Alliance	14,000	9,000	6,500	4,700	1.4	$22,000	$4.70	Chemical precipitation alone.
Canton	50,000	31,000	23,500	20,000	1.2	26,545	1.33	Chemical precipitation alone.
Clyde	2,800	2,500	1,050	1,380	0.8	1,000	0.72	Fine grain filters, no preparatory treatment, natural soil.
Alliance, Fairmount Children's Home	150	150	150	150	1.0	6,000	40.00	Fine grain filters, no preparatory treatment, bank sand.
Dayton, Montgomery County Infirmary	350	350	350	350	1.0	6,000	17.15	Fine grain filters, no preparatory treatment, bank sand.
Gallipolis, Gallia County Infirmary	40	40	40	50	0.8	400	8.00	Fine grain filters, no preparatory treatment, bank sand.
Gallipolis, State Epileptic Hospital	1,450	1,450	1,450	1,450	1.0	12,474	8.60	Fine grain filters, no preparatory treatment, bank sand.
Lancaster, Boys' Industrial School	1,150	1,000	1,150	1,150	1.0	8,900	7.70	Fine grain filters, no preparatory treatment, crushed sandstone.
Mansfield State Reformatory	820	600	820	820	1.0	‡1,000	1.22	Fine grain filters, no preparatory treatment, crushed sandstone.
Massillon State Hospital	1,600	1,600	1,600	1,600	1.0	‡8,000	4.85	Fine grain filters, no preparatory treatment, natural gravel.

Toledo State Hospital	2,000	1,500	2,000	2,000	1.0	‡3,000	1.50	Fine grain filters, no preparatory treatment, natural soil.
Wayne County Childrens' Home.	50	50	50	60	0.8	†1,550	25.80	Fine grain filters, no preparatory treatment, bank sand.
Glenville	9,000	6,000	6,500	4,000	1.6	20,500	5.13	Chemical precipitation, coke strainers, sand filters, fine bank sand.
Oberlin	5,200	4,000	3,400	1,600	2.1	990	0.62	Chemical precipitation, land.
Ashland	7,500	4,000	3,000	4,800	0.6	*5,000	1.04	Septic tanks, filters of natural soil.
Geneva	2,500	2,350	1,200	1,200	1.0	13,500	11.25	Pumping plant, septic tanks, filters of lake sand.
Shelby	6,000	5,000	1,600	2,000	0.8	4,000	2.00	Sedimentation basins, gravel filters.
Sandusky Soldiers' and Sailors' Home	1,125	1,600	1,125	1,125	1.0	10,800	9.60	Septic tanks, filters of lake sand.
Warren, Trumbull County Infirmary	90	90	90	100	0.9	‡1,170	11.70	Pumping plant, septic tanks, filters of crushed coke.
Lakewood	10,000	4,000	7,000	7,000	1.0	24,175	3.45	Septic tanks, contact filters.
Mansfield	24,000	18,000	12,000	14,000	0.9	65,547	4.70	Pumping plant, septic tanks, contact filters.
Marion	19,000	18,000	8,000	8,000	1.0	43,000	5.40	Septic tanks, contact filters, sand filters.
Delaware	10,000	8,000	4,000	1,600	2.5	12,000	7.50	Septic tanks, coke filters.
London	4,000	4,000	500	1,300	0.4	15,000	11.50	Septic tanks, coke filters.
Collinwood, L. S. and M. S. R. R. Shops	1,525	500	1,525	200	7.6	6,800	34.00	Pumping plant, septic tanks, contact filters.
E. Cleveland	8,000	4,000	7,000	4,000	1.8	*56,292	14.00	Pumping plant, septic tanks, strainers, aerators, forced aeration.
Kenton, North District	400	400	400	400	1.0	4,000	10.00	Septic tanks, wave filters.
North Amherst, Ohio Quarries Company	40	40	40	100	0.4	2,800	28.00	Septic tanks, continuous filter.

* Including land.
† Including sewerage system.
‡ Labor performed by inmates.

COSTS OF OPERATION.

Operating expenses available from the principal municipal plants are presented in the next table, as labor and total expenses, cost per person tributary, per capita of total population and per million gallons. The last figure is approximate and is based on the estimated average sewage flow. These operating expenses are further supplemented by fixed charges at 4 per cent. expressed in the last column as total maintenance charges per capita per annum.

The cost of operation ranges from $1.95 per million gallons for the small plant at Clyde, to $47.00 for East Cleveland where the enforced aeration process has been used until the plant was abandoned. Similarly, the annual per capita costs based on the total population range from $0.03 (Lakewood) to $0.78 (East Cleveland). The extra expense incurred when pumping is necessary is indicated by the operating costs at Fostoria, Geneva and Mansfield. General experience suggests the advisability of daily supervision and a permanent caretaker, especially in the larger plants, since by this means plants may be kept in better condition and extensive repairs are rarely necessary. Regular caretakers are employed at the municipal plants of Alliance, Canton, Glenville, Fostoria, Geneva, Lakewood, Mansfield, Marion, Plain City and East Cleveland.

Typical of the different varieties of sewage treatment in Ohio are the operating expenses at Ashland, Geneva, Lakewood, Mansfield and Marion and a study of the detailed expenses as shown in the individual reports of these plants and in the next table enable a fair estimate of operating costs for similar plants.

No separate table has been prepared showing the cost of operation at institutional plants. At the smaller institutions, there are practically no operating charges as the operation of the plant is generally accomplished by a regular employee, together with his other duties. In several of the state institutions, however, where the population is over 1,000, caretakers are employed at salaries, exclusive of board and lodging from $15.00 (Ohio Soldiers' and Sailors' Home, Sandusky) to $35.00 (Gallipolis State Epileptic Hospital). While in municipal plants there are annual fixed charges, in institutional plants the original sum of money necessary for the construction of the plant is directly appropriated by the state or county and no interest charges are considered.

TABLE NO. 105.

Operating and Maintenance Expenses at Principal Municipal Sewage Purification Plants.

Place.	Operating Expenses — 1907.					Capital Charges at 4%.	Total Maintenance.	Total Maintenance Per Capita.
	Labor.	Total.	Per Person tributary.	Per Capita total population.	Per mil. gals. per annum.			
Alliance	$1,742	$3,600	$0.55	$0.26	$6.20	$880	$4,480	$0.32
Canton	2,000	3,200	0.14	0.06	3.50	1,262	4,262	0.08
Glenville	1,620	3,858*	0.59	0.43	8.80	820	4,738	0.53
Oberlin	None	700	0.21	0.13	7.70	40	740	0.14
Clyde	120	120	0.12	0.04	1.95	40	160	0.06
Fostoria	576	1,216	0.24	0.12	12.00	.....	.....	.....
Shelby	600	600	0.37	0.10	6.90	160	760	0.13

* 1908.

TABLE NO. 105 — Concluded.

Place.	Operating Expenses — 1907.					Capital charges at 4%.	Total Maintenance.	Total Maintenance. Per Capita.
	Labor.	Total	Per Person tributary.	Per Capita total population.	Per mil. gals. per annum.			
Ashland	302	393	0.13	0.05	3.20	200	589	0.08
Geneva	600	700	0.58	0.28	10.60	540	1,240	0.50
Lakewood	229	284	0.04	0.03	1.55	966	1,250	0.13
Mansfield	2,800	5,260	0.44	0.22	14.40	2,622	7,882	0.33
Marion	932	1,224	0.15	0.06	5.15	1,720	2,944	0.15
Delaware	None	.....	.....	.....	.....	480	.....	0.05
Plain City	199	199	0.27	0.11	3.10	.....	.....	.....
Westerville	None	.....	.....	.....	.....	116	.....	0.08
E. Cleveland	3,943	6,227*	0.90	0.78	47.00	2,252	8,479	1.06
Kenton, N. District.	104	106	0.26	0.26	14.60	160	266	0.67

*1906.

CONCLUSIONS.

Problems of sewage treatment admit of widely differing solutions dependent upon local conditions. Each problem, therefore, requires special study since there can be no process of treatment that is of general applicability.

The proper management of sewage purification plants is equally important to their design. Poor results from plants in operation, due to official indifference and to ignorance of the principles of successful operation, suggest that they should be subject to frequent inspection and that a central authority should have power to control the operation of plants already built as well as to approve plans proposed for new construction.

Considerable success has attended the efforts of the State Board of Health to increase the efficiency of the sewage plants in operation, but the investigation shows that more legal authority is needed in dealing with the Ohio stream pollution problem.

Further investigation is necessary,

(1) To educate officials newly placed in charge of plants.

(2) To obtain additional information in regard to the disinfection of sewage effluents in their relation to public water supplies.

(3) To obtain reliable data to supplement the present limited information as to the extent of the bacterial pollution of the streams of Ohio, by sewage purification plants, and with special reference to the availability of these streams as sources of public water supply.

(5) To maintain a high standard of operating efficiency in those sewage plants already investigated and to insure similar results in the initial and continued operation of newly constructed plants, the number of which is on a constant increase.

In closing this report, it is desired to acknowledge the many courtesies extended officials of the State Board of Health during the detailed examinations and during the inspections at the different municipal and institutional plants. In many instances the response to requests for assistance has been most hearty, and to the support of local officials is in large part due whatever success has been achieved in the endeavor to raise the standards of operation and efficiency of the sewage purification plants in Ohio.

SUPPLEMENTARY REPORT.

PART I.

EXPERIMENTS UPON THE DISINFECTION OF EFFLUENTS FROM SEWAGE PURIFICATION PLANTS.

During the Board's special investigation of sewage purification plants, arrangements were made with the Bureau of Plant Industry, U. S. Department of Agriculture, at its suggestion to carry out a co-operative study of the problem of the disinfection of the effluents from sewage purification plants. It was proposed at first to confine the experiments to copper sulphate, but later developments resulted in additional experiments with chloride of lime or bleaching powder. An account of these studies has already been published as Bulletin No. 115 of the Bureau of Plant Industry, U. S. Department of Agriculture, but owing to the somewhat limited circulation of this bulletin in Ohio, it seems desirable to include the results of these co-operative studies in a report supplementary to the main report of the Board's special investigation of sewage purification plants.

INTRODUCTION.

The degree to which sewage need be purified before its discharge into a natural watercourse is dependent upon a large number of well known controlling factors. Conditions in different places are so varied that it has not been found practical to develop standards of quality which will be of practical applicability in all instances and in short, the degree of purification for sewage effluents is chiefly dependent upon local conditions as to the degree of dilution available, as to the subsequent disposition of the water as regards its use as a public water supply, in connection with the operation of dairies or in certain cases with relation to shell-fish industries.

In this discussion, it is the bacterial purity of the effluent which is of chief moment. The question of the degree of bacterial purification to which a sewage effluent must be subjected is a subject regarding which there is a decided difference of opinion.(1) In cases where the water which receives the sewage effluent is subsequently used for domestic consumption after water filtration, it is a question whether the effluent of the sewage plant should receive such a thorough treatment as to be free from dangerous pathogenic bacteria or whether the burden of a responsibility should fall entirely upon the operation of the water filtration

[1] Winslow and Phelps. Investigations on the Purification of Boston Sewage. U. S. Geol. Survey, Water Supply and Irrigation Paper 155, 1906.

Reid, George. To what Extent must Authorities Purify Sewage? Surveyor and Municipal and County Engineer, vol. 31, No. 788, pp. 274-275; discussion, pp. 275-278. London, February 22, 1907.

Digby, W. Pollard, and Shenton, Henry C. H. Prevention of the Bacterial Contamination of Streams and Oyster Beds. London, published by the Society of Engineers, 1906. (The same, very slightly abridged) Surveyor and Municipal and County Engineer, vol. 30, No. 777, pp. 653-655, December 7; No. 778, pp. 685-688, December 14; discussion, pp. 688-690. London, 1906.

plant.(2) Some hold that it would be wise to divide the cost of disinfection for sewage effluents between the sewage purification plant and the water filtration plant authorities, although it is evident that such a plan might be productive only of legal complications. While there seems to be no question but that the responsibility of furnishing pure water should fall exclusively upon the authorities who control the water supply, yet it is also apparent that the extent to which an adjacent sewage purification plant should assist in the protection of the raw water from bacterial contamination, can best be determined by some unprejudiced central authority which has jurisdiction over the operation of both sewage and water purification plants.(3)

The experiments which are discussed in this report are chiefly concerned with the disinfection of sewage which has been so purified by methods in general practice that the effluent is rendered stable and no longer shows a tendency to putrefaction. Chemical treatment of sewage for the purpose of removing dangerous bacteria has often been suggested, but earlier attempts were directed almost entirely toward treatment of crude sewage, attempts which experience has shown are usually fraught with entire failure. During recent years, however, it has become recognized that there is some degree of success in the purification of sewage effluents from a bacterial standpoint by treatment with disinfectants. Such measures are of special importance in closely interrelated problems of sewage and water purification, and further in case of hospital sewages in times of epidemical outbreaks.

The Ohio experiments on the disinfection of sewage effluents while chiefly confined to final effluents of different degrees of stability, also relate to the treatment of the effluents from septic tanks, for such effluents would probably have to be considered in the case of small institutions without means for the actual purification of sewage, especially during epidemics of contagious diseases. The disinfectants studied were copper sulphate and chloride of lime or bleaching powder. While copper sulphate has previously been used to disinfect crude and settled sewage,(4) it has been chiefly of service in destroying algal growths in water supplies and in some instances similar growths on sewage filters.(5) Some small scale laboratory tests have been made with both copper sulphate(6) and chloride of lime, although there have been but few practical tests of the applicability of either copper sulphate or chloride of lime in the premises, some information, however, regarding chloride of lime is available from experiments in India.(7)

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(2) Leighton, M. O., River Pollution. Proc. American Water Works Assn., 26th Conv., pp. 61–71; discussion, pp. 71–78. 1906.

Baker, M. N. Notes on Sewage Purification and Public Water Supplies. Proc. American Water Works Assn., 26th Conv., pp. 51–56; discussion by W. P. Mason, pp. 57–58. 1906.

Whipple, George C. Disinfection as a means of Water Purification. Proc. American Water Works Assn., 26th Conv., pp. 266–280. 1906.

(3) Pratt, R. W., Jour. Assoc. Eng. Soc., Oct., 1907, p. 200.

(4) Newcomb, Edwin L. Copper Sulphate as an Adjunct to Sewage Disposal. Jour. New England Water Works Assn., December, 1905.

(5) The Use of Copper Sulphate at Pawtucket, R. I., to Prevent the Clogging of Sewage Filter Beds by Blanket Growth of Micro-organisms. (From the November-December Bul. of the Rhode Island State Board of Health), Engineering News, vol. 57, No. 14, pp. 379–380, 2 figs. New York, April 4, 1907. The same, Engineering Record, vol. 55, No. 13, pp. 413–414, illus. New York, March 30, 1907.

See also p. 000.

(6) Johnson, George A. Report on Sewage Purification at Columbus, Ohio, Made to the Chief Engineer of the Board of Public Service. Columbus, Ohio, 1905, pp. 471–479.

Rideal, Samuel. Sewage and Bacterial Purification of Sewage. 3d ed., London and New York, 1906, p. 174.

(7) Indian Government. Resolutions on the Working of Septic Tanks. Calcutta, January 6, 1906.

Probably the first experiments in the United States with reference to the use of chloride of lime in the disinfection of sewage effluents were made at the sewage experiment station of the Massachusetts Institute of Technology.[8] These experiments were completed shortly before there was begun the Ohio studies with this chemical and it was from suggestions obtained from the Massachusetts work that the Ohio disinfection studies were further continued with the use of bleaching powder as the disinfectant.

GENERAL CONDUCT OF EXPERIMENTS.

Under the coöperative agreement, the experiments planned by the officials of the Bureau of Plant Industry were directed by the officials of the Ohio State Board of Health. To carry out the detailed work in the field there were sent two special agents from the Bureau of Plant Industry, Messrs. J. O. Meadows and C. P. Hoover. All expenses incidental to the investigation were paid by the Bureau of Plant Industry.

Experiments with copper sulphate were carried out at Westerville, the Boys' Industrial School, Lancaster, and at Marion, Ohio. Some preliminary work was also done at St. Mary's of the Springs near Columbus. Tests with chloride of lime were made only at the Boys' Industrial School and at Marion.

To carry out these experiments which were on a practical scale there were first constructed experimental plants for the application of chemicals. These included storage tanks, orifices boxes with float control and facilities for a certain storage period of the treated effluent.

The analytical work involved in these studies comprised chemical analyses of average samples of the effluent before and after treatment, together with bacterial analyses of several samples to show the effect of the disinfectants used upon the removal of B. coli, acid formers and total numbers of bacteria. The greater part of the chemical work and practically all of the bacterial work, with the exception of the preparation of media, was carried out on the field. Methods of chemical and bacterial analyses conformed to those prescribed by the Committee of Standard Methods of the American Public Health Association, except that bile broth was used in the latter part of the work on coli differentiation.

COPPER SULPHATE EXPERIMENTS.

Experiments with copper sulphate as a disinfectant were continued from Sept. 17, 1906 to Jan. 31, 1907, and were carried out at St. Mary's of the Springs, Westerville, Boys' Industrial School, Lancaster, and Marion, Ohio.

St. Mary's of the Springs.

St. Mary's of the Springs is a convent school about three miles from Columbus and has a population of about 175. At the present time, the sewage of the institution is collected in two connected circular tanks. The tanks are 10 feet in diameter, about 6 feet in depth to the flow line and each of about 3,050 gallons capacity. From the second tank the sewage flows by gravity into a small brook through some 12 feet of 8-inch tile. Rough measurements indicate that the flow of sewage is in the vicinity of 12,000 gallons for 16 hours and that there is practically no flow after 10:00 o'clock P. M. This rough treatment of the sewage

[8] Phelps, E. B. and Carpenter, W. T. The Sterilization of Sewage Filter Effluents. Technology Quarterly, vol. 19, No. 47, pp. 382-403. Boston, December, 1906.

Phelps, E. B. The Sterilization of Sewage Flter Effluents. Science, vol. 25, No. 647, pp. 808-809. Garrison, N. Y., May 24, 1907.

of the institution, of course, affords practically no actual purification and the sewage as discharged is, of course, highly putrescent.

Application of Copper Sulphate. Since September 1, 1905, it has been the practice of the health department of the city of Columbus to apply daily six pounds of copper sulphate to the sewage as it flows from the first into the second reservoir. It is stated that one-half of the quantity of chemical applied is introduced at 9:00 o' clock A. M. and the remainder at 3:00 o'clock P. M. The approximate concentration of copper sulphate is about 63 parts per million. The copper sulphate is added in a dry state and is placed into a perforated enamel pail, which is then lowered into the sewage to a point opposite the inlet pipe from the first reservoir. The copper sulphate thus suspended awaits the somewhat erratic solvent action of the incoming sewage and at times the entire day's dose is not completely dissolved in 24 hours.

Field Work. To learn the efficiency of this treatment, there were made tests of the treated effluent on two separate days. On each occasion at half hourly intervals for a period of 7 hours, there were collected samples of the untreated sewage as it entered the second tank and of the treated sewage as it flowed from the second tank; the several portions were mixed in equal volumes to form a composite average. Bacterial analyses were started in the field for the determination of total numbers, acid formers and *B. coli;* all of the tests were made in duplicate. Other observations included measurements of the sewage flow at half hourly intervals.

Efficiency of Treatment. In Table No. 1 are listed the results of bacterial analyses made during the two days of the test. The average number of total bacteria in the sewage before and after treatment was 5,600,000 per cubic centimeter; in the treated sewage an average of 65,000, a reduction of about 99 per cent. Platings of the treated effluent incubated for 24 hours at 37 degrees C. showed a development of 250,000 bacteria, of which 36,750, or 14.7 per cent. were acid formers. Unfortunately no analyses were made to learn the number of acid formers in the untreated sewage so that it is not possible to determine the percentage reduction of bacteria capable of development at this higher temperature although from past experiences it seems reasonable that the reduction at 37 degrees C. would be slightly greater than that at the lower temperature. From each plate grown at 37 degrees C. ten colonies fished onto lactose azolitmin agar, subcultured and carried through full determinative tests gave positive results and were considered *B. coli.*

TABLE NO. 1.

Results of Bacterial Analyses at St. Marys of the Springs.

Date. 1906.	Hour.	Bacteria per Cubic Centimeter.*		Colonies at 37 deg. C. After Copper Treatment.		Percentage Removal Total Bacteria.
		Untreated.	Treated.	Total.	Red.	
Sept. 17.....	9:30 A.-4:30 P.	5,900,000	60,000	250,000	3,500	99.0
Sept. 18.....	8:15 A.-3:15 P.	5,300,000	70,000	250,000	70,000	98.8

* Average of half-hourly duplicate analyses.

Note: Untreated sewage not examined for red colonies. (See text).

Costs. The cost of treating the settled sewage of St. Mary's is practically that due to the chemical and operating costs, as the construction costs for the plant are practically negligible. With copper sulphate at six cents per pound and a sewage flow of 12,000 gallons in twenty-four hours, the cost for chemicals is three cents per 1,000 gallons, using six pounds of copper sulphate per day. The labor cost may be considered to be 25 cents per day.

Similar plants, applying copper sulphate in the proportion of 63 parts per million to a sewage flow of 12,000 gallons; would require about 6 pounds of copper sulphate daily, costing 36 cents per day. On an annual basis including labor one hour per day at 25 cents per hour, the chemical and maintenance cost would be about $222.65, proportioned as follows:

2,190 lbs. copper sulphate at 6 cents per lb.....	$131 40
Labor, 365 hours, at 25 cents per hour.....	91 25
	$222 65

Capitalized at 5 per cent. the investment necessary would be $4,500.

For crude sewage, much better results could probably be obtained by using 100 parts of copper sulphate per million gallons of sewage. For treating 12,000 gallons at this rate, the cost would be 60 cents a day for chemical, or a total annual cost of $310.25, corresponding to a capitalization of $16,200.

WESTERVILLE.

The first actual experimental work in connection with this investigation was carried out at the sewage purification plant of the village of Westerville. This sewage plant comprises septic tanks, cinder contact filters and secondary filters of similar material. The plant has been fully described and discussed in the main report (See pp. 571-578). It will be recalled that the plant is operated on a continuous basis and that while the effluent from the primary filters is at times non-putrescible, after protracted continuous operation it tends to become unstable and contains considerable crude organic matter. Since the effluent from the primary filters was the more accessible for copper sulphate treatment, by suitable piping it was conducted to an orifice box so that a known and constant quantity could be diverted for the experiments.

Application of Copper Sulphate. Copper sulphate crystals were dissolved in barrels 10 in number and connected by suitable piping which lead to an orfice box from which there was maintained a constant flow at the rate of 41,000 gallons in 24 hours. The sewage effluent was used for preparing the chemical solution and contained so high an alkalinity that it was necessary to almost neutralize the carbonates with sulphuric acid, as otherwise the copper salt would have been completely precipitated.

From the orifice box, the copper solution flowed into a storage reservoir. This was a rough excavation about 10 x 15 feet in plan and 2 feet deep and contained 1 foot from the outlet end a vertical baffle which was submerged to a depth of 18 inches. A small baffle placed longitudinally at the point of entrance of the effluent and the copper sulphate solution served to effect a thorough mixing of the effluent and disinfectant solution. The storage reservoir was of about 2,000 gallons capacity and afforded a storage period of about 1.25 hours. The cost of constructing this experimental plant was about $67.

Field Work. Chemical analyses in the field comprised a determination of the free carbonic acid and of the alkalinity before and after treatment. The other data shown in Table No. 2 were the result of analyses made in the laboratory. Samples for chemical analyses were collected at hourly intervals and were mixed

in equal portions at the end of a day's run. Samples for bacterial analysis were similarly collected from the sewage effluent before and after treatment. The bacterial work comprised the determination of total numbers in the untreated and treated effluent and in the plating for *B. coli* on lactose azolitmin agar; all platings were in duplicate. From the colonies developing at 37 deg. C. from one each of the duplicate plates three colonies were fished and were carried through *full determinative tests* for *B. coli*. As the concentration of copper sulphate increased and the bacteria began to decrease in some cases all of the red colonies were subcultured.

Quantities of Disinfectant Applied. The initial run was made at a concentration of 5 parts per million and was followed by a gradually increasing rate of application until there was reached a concentration of 67 parts per million. It was the general practice to apply copper sulphate at a given concentration for two consecutive days. It is to be stated that the volume of effluent treated was practically the entire flow from the village during the hours the experiments were conducted.

Efficiency of Treatment. The results of the bacterial analyses which cover the 16 runs at Westerville are shown in Table No. 2. These results show that the removal of bacteria developing at 20 deg. C. ranged from 59 to 95 per cent. depending upon the concentration of the applied disinfectant and also upon changes in temperature.[9] As the data indicate, there was a decided deterioration in the character of the effluent from the primary filters during the later tests and the increased quantity of organic matter then present possibly to some degree offset the effect of a greatly increased concentration of copper sulphate. The removal of bacteria developing at 37 deg. C. on lactose azolitmin agar was variable and ranged from 28 to 96 per cent.; that of the acid forming colonies ranged from 66 to 100 per cent. These tabulated data suggest the large numbers of bacteria which are present in an imperfectly purified sewage effluent as is represented by that at the Westerville plant.

[9] Moore, G. T., and Kellerman, K. F., Bul. 76, Bureau of Plant Industry, p. 12, 1905. Johnson, George A., Report on Sewage Purification at Columbus, Ohio, Appendix X, p. 478, 1905.

TABLE NO. 2.

Volume of Flow, Temperature, Organic and Suspended Matters, and Efficiency of Copper Sulphate Applied, Westerville, Ohio.

Date.	Copper sulphate, parts per million.	Volume of effluent treated.	Temperature.		Parts per million.											Putrescibility.	Bacteria per cubic centimeter.						Bacterial removal.		Per cent positive with test for *B. coli.*	
					Carbonic acid.					Nitrogen as—				Suspended matter.			20° C.		37° C.							
					Free.		Half bound.												Total count.		Red colonies.					
			Air.	Effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Oxygen consumed.	Organic.	Free ammonia.	Nitrites.	Nitrates.	Total.	Volatile.		Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	20° C.	Total colonies.	Red colonies.	Untreated effluent.	Treated effluent.
1906.		*Galls.*	°C.	°C.																			*P ct*	*P.ct.*	*P.ct.*	*P ct*	*P ct*
Oct. 2	5	41,000	21.0	18.0	34	23	194	198	14	3.5	7.0	0.07	1.5	44	23	+	3,100,000	205,000	83,000	207,000	10,000	1,100	94	—149	89	13	67
3	5	41,000	18.5	17.5	43	26	220	229	12	1.3	8.0	.18	1.0	35	16	+	9,100,000	2,100,000	205,000	42,000	1,400	100	77	80	93	27	63
5	6.7	41,000	22.5	18.0	40	32	210	209	15	9.7	6.0	.16	1.0	24	6	+	430,000	120,000	20,000	14,500	6,500	325	73	28	95	33	45
6	6.7	41,000	13.0	16.0	40	32	177	178	9	2.5	9.0	.21	1.5	37	27	+	60,000	24,000	18,000	5,500	6,000	1,400	66	70	77	21	67
9	10	41,000	7.5	12.0	28	27	192	191	5	1.3	6.4	.16	1.5	26	19	+	75,000	16,000	66,000	11,000	3,400	1,500	79	84	66	5	22
10	10	41,000	4.0	10.0	26	24	202	210	6	1.1	6.0	.....	1.8	16	9	+	46,000	16,500	28,000	8,000	1,800	450	65	72	75	....	18
15	13	41,000	23.5	15.0	36	30	230	236	6	1.1	7.2	.20	1.7	10	9.6	+	60,000	25,000	25,000	4,000	2,500	250	59	84	90	....	40
16	13	41,000	23.5	15.5	37	32	238	238	7	1.9	8.0	.17	1.5	10	8.8	+	70,000	20,000	48,000	7,000	6,600	900	72	86	87	....	82
19	20	41,000	18.0	16.0	35	33	218	214	15	4.9	4.0	.18	1.7	16	8.8	+	145,000	26,000	87,000	12,500	1,600	110	82	86	93	....	6
20	20	41,000	17.5	15.5	32	30	221	216	12	3.3	5.6	.18	1.5	8	3.6	+	88,000	13,000	69,000	10,000	1,500	110	85	86	93	....	38
25	29	41,000	8.0	14.0	40	36	202	119	14	4.6	8.8	.08	0.8	34	15	+	60,000	3,900	24,000	6,000	1,200	10	75	75	99	....	33
26	29	41,000	12.0	14.5	40	38	211	201	10	3.9	9.0	.07	0.7	36	32	+	60,000	6,200	50,000	3,000	2,500	15	94	94	99.5	....	66
Nov. 3	40	41,000	14.0	13.0	41	39	176	173	15	1.5	11.0	.07	0.5	17	17	+	370,000	7,000	130,000	6,000	3,000	00	95	96	100	.....	.....
5	40	41,000	19.5	14.0	....	....	....	....	....	.....	.....	.....	.....	....	.....	+	46,000	13,000	51,000	5,000	11,000	300	91	91	97	....	62
8	67	41,000	19.5	13.0	41	40	218	214	39	5.1	10.0	.03	0.2	30	.....	+	175,000	47,000	115,000	16,000	7,700	800	86	87	88	....	41
9	67	41,000	16.0	13.5	39	38	210	206	16	3.9	10.0	.05	0.0	36	.....	+	220,000	21,500	47,000	12,000	6,500	600	74	75	91	....	33

Costs. On the basis of treating daily 41,000 gallons of effluent of the primary contact filters, the initial cost of a plant for applying the germicidal chemical would be $70 in round numbers. Considering a satisfactory removal of pathogenic organisms to be produced by a concentration of 40 parts per million, the daily quantity of copper sulphate required would be 13.7 pounds, the cost for chemicals would be about 82 cents and labor two hours at 25 cents, 50 cents. The annual cost with copper sulphate at 6 cents a pound and labor at 25 cents per hour would be as follows:

5,000 lbs. copper sulphate at 6 cents per lb.....	$300 00
Labor, 730 hours, at 25 cents per hour.....	182 50
	$482 50

Capitalized at 5 per cent. the required investment would be $9,650.

Boys' Industrial School, Lancaster.

Following work at Westerville, the experiments were continued at the Boys' Industrial School, near Lancaster, Fairfield County. This is a state institution and has a population of about 1,150. Sewage from the institution is treated on 23 sand filters which receive crude sewage which has been subjected to a rough screening only as a preparatory treatment. The effluent from the filters flows into a main collecting drain which serves also to carry off some surface water and leads to a small brook tributary to the Hocking River. (For details of this plant, see main report pp. 627-634).

At this plant, in distinction from applying a constant quantity of disinfectant to a constant volume of effluent, as was the case at Westerville, it was thought most practicable to apply the chemical to the entire effluent flow and to carry out the experiments with a view to learning the quantity of copper sulphate required to destroy coli-like organisms when the sewage was flowing at a maximum rate.

Application of Copper Sulphate. Suitable tanks were set up for the preparation of the copper sulphate solution and in a manner similar to the arrangement at Westerville, the flow of chemical was controlled by an orifice box. To provide for a storage for the treated effluent, a dam was constructed about 200 feet from the outlet of the main effluent drain and the shallow basin thus formed afforded a storage period of from 3 to 4 hours depending upon the rate of flow of the effluent. To gage the flow of effluent, there was also provided facilities for weir measurement. The untreated effluent was used in the preparation of the chemical solution and no difficulty was experienced in obtaining clear solutions since the sewage at Lancaster is unusually soft. At the beginning of the test the quantity of copper sulphate required was such as to afford a concentration of 5 parts per million based upon a rate of flow of effluent of 150,000 gallons in 24 hours during the hours the experiments were conducted. It is obvious that the actual concentration of chemical varied widely corresponding to the changing rate of flow from the filters. The quantities of copper sulphate applied were gradually increased until the average concentration was 22 parts per million. The rate of flow of copper sulphate solution was practically constant at 0.75 gallon per minute. The first series of experiments comprised seven runs from Nov. 16 to Dec. 4, 1906. Three duplicate runs were made a few months later during the colder weather of January, 1907.

Field Work. Bacterial samples of the effluent before and after treatment were collected at half hourly intervals and were examined in a manner similar to that adopted at Westerville. As bacterial development began to increase with an increasing concentration of copper sulphate, in some instances all of the acid form-

ing colonies were sub-cultured. The bacterial work was carried out entirely in the field. The chemical work comprised the usual determinations which for the greater part were made in the field. Sampling of the treated effluent was commenced three hours after that of the untreated effluent to allow for the period of storage. Special chemical samples were collected at two hourly intervals for the determination of free carbonic acid and dissolved oxygen.

Efficiency of Treatment. The summarized results obtained during the experiments at Lancaster are presented in Tables Nos. 3 and 3a. It is evident from these results that the efficiency of the treatment was distinctly greater than that at Westerville and that although the removal of total bacteria even at the higher concentration studied, was only moderate, yet a concentration of 13 parts per million was sufficient to afford a complete removal of acid forming colonies and *bacillus coli.* It seems probable that the more efficient action of the chemical at Lancaster is to be attributed to the greater organic purity of the effluent[10] and the absence of complicating carbonates. The results of the supplementary tests made from Jan. 29 to 31 inclusive, 1907, showed substantially similar results. The organic character of the effluent was somewhat improved and this fact no doubt tended to offset the effect of the lower temperature which then prevailed.

Costs. The daily application of copper sulphate to the Lancaster sand filter effluent with a flow of 160,000 gallons, would require 17.3 pounds of copper sulphate and the cost of chemical would be about $1.04 per day, based on applying 13 parts copper sulphate per million gallons of the effluent.

The cost of constructing the Lancaster plant used in these experiments and capable of treating sewage at the rate of 160,000 gallons for six hours, was $29. However, a fair estimate of the cost of a plant under practical conditions for continuous treatment would be about $92., proportioned as follows:

2 solution tanks, 1,400 gals. capacity	$45 00
Orifice box	8 75
Brass orifice	2 00
Float control	1 25
Pipe	5 00
Lumber	5 00
Labor	25 00
	$92 00

The operating cost per annum on the above basis would be as follows:

6,325 lbs. copper sulphate, at 6 cents per lb	$379 50
Labor, 365 days, at $2.00 per day	730 00
	$1,109 50

Capitalized at 5 per cent. this would represent an investment of $22,000.

[10] Johnson, George A. Report on Sewage Purification at Columbus, Ohio, 1905, p. 474.

TABLE NO. 3.

Volume of Flow, Carbonic Acid, Organic and Suspended Matters, and Efficiency of Copper Sulphate at Different Concentrations, Boys' Industrial School, Lancaster, Ohio.

Date.	Copper sulphate, parts per million.			Volume of effluent			Temperature.		Parts per million.										Bacteria per cubic centimeter.				Bacterial removal.		Per cent positive with test for *B. coli*.	
									Carbonic acid.					Nitrogen as—				Suspended matter.								
									Free.		Half bound.		Oxygen consumed.							20° C.		37° C.			37° C.		
																					Total count.		Red colonies					
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Air.	Effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.		Organic.	Free ammonia.	Nitrites	Nitrates.	Total.	Volatile.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent	Untreated effluent.	Treated effluent	20° C.	Total colonies.	Red colonies.	Untreated effluent.	Treated effluent.
1906.				*Galls.*	*Galls.*	*Galls.*	*°C.*	*°C.*																	*P ct*	*P ct*	*P ct*	*P ct*	*P ct*
Nov. 16	8.8	6.4	7.8	102,000	90,000	88,000	8.3	10.0	11	8	22	22	16	4.4	5.0	0.30	5.0	74	31	64,000	48,000	6,750	1,300	859	131	25	81	85	50	33
19	7.5	2.4	4.2	363,000	118,000	209,000	8.0	9.3	25	22	10	15	18	5.3	2.5	.30	25.0	64	28	130,000	26,500	14,800	5,400	936	95	80	64	90	33	28
20	8.9	6.0	7.0	220,000	151,000	189,000	21.6	12.5	27	21	16	30	....	....	....	....	....	....	....	78,000	11,000	14,000	700	50	1	86	95	98	60	0
21	14.0	13.0	14.0	138,000	126,000	129,000	23.0	13.5	16	13	18	18	16	4.7	2.3	.50	25.0	69	22	75,000	9,600	15,500	600	75	0	88	97	100	33	0
22	25.0	21.0	22.0	126,000	118,000	122,000	4.4	11.0	6	7	11	15	13	3.6	5.0	.24	25.0	71	31	55,000	6,800	5,700	200	95	0	88	97	100	54	0
27	11.0	7.5	9.1	118,000	80,000	96,000	5.5	9.0	17	10	17	18	31	2.0	5.0	.05	17.0	62	20	225,000	28,000	21,000	1,600	360	5	88	98	99	80	57
Dec. 4	9.4	8.3	8.3	80,000	70,000	80,000	2.5	6.0	11	11	18	17	21	6.5	2.5	.30	5.0	85	52	70,000	3,800	5,300	180	310	8	96	97	98	....	14

TABLE NO. 3a.

Volume of Flow, Temperature, Organic and Suspended Matters, and Efficiency of Copper Sulphate Applied to Effluent, Boys' Industrial School, Lancaster, Ohio.

Date.	Copper sulphate, parts per million.			Volume of effluent. treated.			Temperature.		Parts per million.												Bacteria per cubic centimeter.						Bacterial removal.		Per cent positive with test for *B. coli*.	
										Nitrogen as —				Suspended matter.		Carbonic acid.						20° C.		37° C.				20° C.	37° C.		
																Free.		Half bound.						Total count.		Red colonies					
	Maximum	Minimum.	Average.	Maximum.	Minimum.	Average.	Air.	Effluent.	Oxygen consumed.	Organic.	Free ammonia.	Nitrites.	Nitrates.	Total.	Volatile.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Dissolved oxygen.	Putrescibility.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.		Total colonies.	Acid colonies.	Untreated effluent.	Treated effluent.
1907				*Galls.*	*Galls.*	*Galls.*	°C.	°C.																				*P ct*	*P ct*	*P ct*	*P ct*	*P ct*
Jan. 29	10	7.9	8.5	191,000	150,800	177,000	—0.5	4.0	11	0.7	3.6	0.36	2.0	37	33	14	13	22	22	6.8	0	49,000	5,400	8,800	1,300	250	100	89	85	60	75	25
30	13	12	13	177,800	150,800	158,000	—2.0	4.0	13	1.6	4.0	1.20	2.0	18	18	14	13	21	21	....	0	58,000	5,300	9,000	300	600	1	91	97	99.9	57	25
31	6.6	4.9	5.8	204,300	150,800	171,400	0.0	4.0	14	1.2	4.0	1.20	2.0	14	13	14	13	22	21	....	0	82,000	8,000	12,000	565	260	45	88	96	83	60	....

MARION.

Experiments at Marion were carried out from December 19, 1906, to January 14, 1907. Nine different concentrations of copper sulphate were studied.

The sewage purification plant at Marion comprises septic tanks, contact filters and subsidiary sand filters. (See detailed description 535-538). The volume of sewage flow was about 600,000 gallons daily.

Application of Copper Sulphate. There was first studied the effect of applying copper sulphate to the effluent of the sand filters. To control the application of the chemical there was erected a storage tank with a capacity of 1,780 gallons, provided with suitable piping and arrangements for the control of the flow by means of a float controlled orifice box. Water for dissolving the chemical was pumped to the tank by wind power. The chemical solution discharged into the outlet weir chamber at a point about 2 feet from the effluent outlet pipe and about 4 feet on the upstream side of the weir.

To provide a storage period, a dam was built in the effluent sewer in the manhole about 900 feet west of the plant. This construction was supplemented by the erection of a cofferdam and weir at the outlet of the effluent sewer into Rock Swale Creek. The cofferdam was composed of 6-inch sheathing and was of such a height that in all but flood stages, the copper-treated effluent would discharge into the creek in a clear sheet. The object of thus protecting the outlet was to overcome possible contamination of the effluent after disinfection by back water from the creek which undoubtedly receives considerable domestic sewage. During the experiments, the waters of the creek rose so as to completely overflow the cofferdam, but on such days no tests were made, and on all of the runs it was possible to collect samples of the effluent without danger of contamination from the waters of the creek.

The tests were conducted similarly to those made at Westerville and Lancaster. Bacterial studies were practically the same but more detailed chemical analyses were undertaken. On the first test, copper sulphate was applied at a concentration of 5 parts per million based upon an effluent flow at the rate of 400,000 gallons in 24 hours. On successive runs, copper sulphate was increased to concentrations of 7, 10, 13, 20, 40, 67, 100 and 200 parts per million.

The flow of copper sulphate solution was at the rate of 2 gallons per minute. As was the case at Westerville it was necessary to use sulphuric acid in preparing the disinfectant to prevent a precipitation of the copper salts.

Field Work. The Marion sewage purification plant is hand operated in the day time only; during the night the contact filters are operated continuously. All tests, however, were made between the hours of 7:00 o'clock A. M. and 5:00 o'clock P. M. when the normal hand operation of the plant prevailed. From 7:00 o'clock until 10:00 o'clock P. M. practically no effluent is discharged into the effluent channel and hence all the tests began about 10:00 o'clock A. M. Samples were collected at half hourly intervals with an allowance for a storage period of one hour. The average storage period was learned by a number of tests with dyestuffs. The average results with a sewage effluent flow of from 530,000 to 840,000 gallons was about one hour.

Efficiency of Treatment. As the experiments progressed, concentrations which appeared successful for example, at Lancaster to effect upwards of 99 per cent. of removal of *B. coli* and a substantial percentage of total bacteria showed a greatly decreased efficiency under Marion conditions. As the results with a concentration of 40 parts per million was so disappointing it was decided to increase the concentration to 110 parts per million, although such a large quantity of disinfectant would of course be impracticable on the grounds of cost. The

data presented in Table No. 4 show that even at this high concentration, the removal of total bacteria was only 92 per cent. and that of fermenting organisms 93 per cent. These results were not so encouraging as those obtained at Lancaster and it is probable that the small storage period and the greater organic content of the Marion effluent is largely the explanation. Several investigators[11] have shown that time of contact is an important element in the successful application of copper sulphate as a germicide. Furthermore, the sewage effluent at Marion is very hard and possibly the feature of carbonates may be taken in explanation of the somewhat poor results obtained.

Costs. The application of copper sulphate to the Marion sand filter effluent with a daily flow at the rate of 600,000 gallons on a basis of applying 20 parts of copper sulphate to each 1,000,000 gallons of effluent would cost $6 a day for chemicals. The cost of constructing a plant for applying the copper sulphate would be about $151, as follows:

Three 1500-gallon solution tanks	$99
Pipe and lumber	20
Orifice box and control	10
Brass orifice	2
Labor	20
	$151

The cost of treatment annually on the above basis, that is, using copper sulphate, to the extent of 20 parts per million would be about $2,920, proportioned as follows:

36,500 lbs. copper sulphate, at 6 cts per lb	$2,190
Labor, one man, 365 days, at $2.00	730
	$2,920

Capitalized at 5 per cent. this would represent an investment of $58,000.

[11] Gildersleeve. Studies on the Bactericidal Action of Copper on Organisms in Water. American Journal of Medical Science, n. s., Vol. 129, No. 5, pp. 754-760. Philadelphia and New York, May, 1905.

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Kraemer, Henry. Copper Treatment of Water. American Journal of Pharmacy, vol. 16, No. 12, pp. 574-579. Philadelphia, December, 1904.

Phelps, E. B. Experiments on the Storage of Typhoid-Infected Water in Copper Canteens. American Public Health Association, Report, vol. 31, part 1, pp. 75-90, 1905.

Moore, G. T., and Kellerman, K. F. Method of Destroying or Preventing the Growth of Algae and Certain Pathogenic Bacteria in Water Supplies. Bul. 64, Bureau of Plant Industry, 1904. Copper as an Algicide and Disinfectant in Water Supplies. Bul. 76, Bureau of Plant Industry, 1905.

Kellerman, K. F., and Beckwith, T. D. The Effect of Copper upon Water Bacteria. Bul. 100, Pt. VII, Bureau of Plant Industry, pp. 57-71. 1907.

TABLE NO. 4.

Volume of Flow, Temperature, Organic and Suspended Matters, and Efficiency of Copper Sulphate Applied to Effluent, Marion, Ohio.

Date.	Copper sulphate, parts per million.			Volume of effluent treated.			Temperature.		Parts per million.														Bacteria per cubic centimeter.						Bacterial removal.			Per cent positive with test for *B. coli*.	
									Oxygen consumed.	Nitrogen as—				Susp. Matter.		Carbonic acid.				Dissolved oxygen.	Putrescibility.	20° C.		37° C.						37° C.			
																Free.		Half bound.				Untreated effluent.	Treated effluent.	Total count.		Red colonies.		20° C.	Total colonies.	Acid colonies.	Untreated effluent.	Treated effluent.
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Air.	Effluent.		Organic.	Free ammonia.	Nitrites.	Nitrates.	Total.	Volatile.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.					Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.					
				Galls.	*Galls.*	*Galls.*	*°C.*	*°C.*																				*P ct*	*P ct*	*P ct*	*P ct*	*P ct*
1906																																	
Dec. 19	5	3	3	732,000	391,000	640,000	3.1	6.0	12	2.3	5.6	0.22	4.4	21	10	21	21	142	140	6.5	0	290,000	67,000	93,000	44,000	1,200	1,300	77	53	8	38	63
20	9	4	6	596,000	284,000	469,000	3.0	8.2	9	7.3	4.6	.18	0.0	29	13	17	17	142	142	4.0	0	400,000	78,000	390,000	59,000	3,200	1,200	80	85	62	29	50
27	16	5	7	779,000	249,000	553,000	1.5	5.5	17	9.9	6.0	.15	4.4	22	11	26	24	143	143	4.7	0	410,000	170,000	75,000	36,000	12,000	4,300	58	52	63	....	44
28	22	7	10	732,000	217,000	553,000	3.6	7.5	14	2.3	5.6	.20	5.0	23	10	36	35	139	139	4.0	0	450,000	125,000	140,000	25,000	16,000	4,800	72	82	70	....	44
1907																																	
Jan. 2	36	10	13	829,000	217,000	596,000	6.0	8.3	15	2.1	5.0	.50	6.0	21	12	26	26	128	128	6.8	0	380,000	97,000	58,000	19,000	6,000	2,500	74	67	60	....	78
7	27	12	17	926,000	427,000	686,000	15.0	10.0	10	6.3	0.0	.80	6.0	23	11	25	25	110	110	6.8	0	84,000	33,000	26,000	12,000	4,000	1,800	61	54	55	....	67
9	37	27	32	985,000	732,000	829,000	4.7	7.7	10	3.1	4.0	.84	6.0	39	16	16	16	114	114	6.4	0	22,000	5,400	38,000	13,000	5,000	1,000	75	67	80	....	33
10	53	40	48	985,000	779,000	829,000	.8	7.0	10	2.3	4.0	.90	6.0	29	10	17	17	128	128	5.9	0	36,000	7,500	21,000	4,000	5,500	450	78	81	92	....	53
14	154	110	116	732,000	525,000	689,000	9.8	9.5	10	1.9	3.6	.40	4.0	24	11	27	26	123	123	6.1	0	84,000	7,000	28,000	2,000	5,000	560	92	93	89	....	31

CHLORIN EXPERIMENTS.

After completing the experiments with copper sulphate, it was decided to discontinue the copper work and study the effect of applying chloride of lime or bleaching powder in the disinfection of sewage effluents of different degrees of purity. The use of hypochlorites or electrolytic chlorin has been studied for some years and chlorin treatment has been tried at a few sewage plants. Generally speaking, these processes were expected to purify the sewage as well as to disinfect and they were necessarily unsuccessful. Considerable work[12] has been carried out at hospitals where it is desirable to disinfect the crude sewage and it appears that chlorin may be so used with satisfactory results, and without influencing subsequent purification by bacterial processes.[13] As has already been stated, the rational function of germicides in practical sewage purification work on a large scale is the disinfection of the effluent which has previously received a more or less thorough purification. The process has been applied to the effluent from the septic tanks[14] and in some cases to those from well operated sand filters and it is this phase of the question which has recently received special consideration on account of the relation of sewage purification and sewage disposal to the contamination of shellfish.

The Ohio experiments with chloride of lime were first carried out at Lancaster and comprised three runs with the sand filter effluent, together with a few laboratory experiments in regard to the absorption of chlorin by organic matter in the sand filter effluent and also in artificial mixtures containing different quantities of crude organic matter.

Calcium hypochlorite or bleaching powder was selected as the most inexpensive and practical source of chlorin for these experiments. The commercial product costs on an average 3 cents a pound or in large quantities may be purchased for 2½ or 2¾ cents a pound. Depending upon the degree of exposure to the atmosphere the commercial product purchased in Columbus, Ohio, showed a range on analysis in available chlorin (Cl) from 18 to 25 per cent. In some localities, bleaching powder in sealed containers can be purchased at from 1½ to 2 cents a pound. For the purpose of these field tests and for greater accuracy and convenience it was decided to use a product on the market in sealed containers costing 4 cents a pound. This product showed on analysis 34 per cent. available chlorin and was, of course, subject to less variation than the cheaper product purchased in bulk and subject to decreasing chlorin content due to exposure.

According to the experience gained at Lancaster and Marion the preparation of the hypochlorite solution is an important feature of the successful treatment of sewage effluents with chlorin. It was found that unless special precautions are taken in dissolving the bleaching powder, there remain many large lumps which inclose chlorin whereby the efficiency of a given weight of bleaching powder is materially reduced. The method of preparing the bleaching powder found by experience to give the best results is as follows:

A weighed quantity of bleaching powder is placed into a shallow box and covered with sufficient water to form a smooth paste. More water is then added until the heavier particles settle out, thus allowing the soluble and finely divided chloride of lime to be decanted. After decantation, more water is added, the

[12] Schumacher. Die Desinfektion von Krankenhausgruben mit besonderer Berücksichtigung des Chlorkalkes und ihre Kontrolle. Gesundheits-Ingenieur, 28th year, No. 22, pp. 361-368, Aug. 10; No. 23, pp. 376-384, Aug. 19; No. 24, pp. 393-397, Aug. 30, Munich, 1905.

[13] Dunbar and Korn. Zur Desinfection von Abwässern mit gleichzeitiger Reinigung derselben. Gesundheits-Ingenieur, 27th year, No. 2, pp. 17-20. Munich, January 20, 1904.

[14] Indian Government. Resolutions on the Working of Septic Tanks.

Red Bank, N. J., Rep. N. J. State Sewerage Commission, 1907. Red Bank, N. J., Rep. N. J. State Sewerage Commission, 1908, pp. 113-126.

coarse lumps broken up and the process repeated until as much as possible has gone into solution. The importance of thoroughly mixing the chloride of lime solution and of grinding the dried chloride of lime as finely as possible cannot be too strongly emphasized. A loss of from 10 to 30 per cent. may easily arise, especially in the case of low grade bleaching powder. Experiments with a high grade bleaching powder of known strength indicate that the loss of chlorin when the above precautions are taken is not more than one per cent.

The experiments with chlorin were conducted at the Boys' Industrial School, Lancaster, and at Marion, Ohio. The experimental plants for applying copper sulphate were used with substantially no changes. The general conduct of the experiments was practically the same as in the copper sulphate tests.

Boys' Industrial School, Lancaster.

Chlorin experiments at Lancaster were carried out on Feb. 8, 13 and 15, 1907. The quantity of sewage effluent treated was at the rate of 208,000, 175,000 and 95,000 gallons, respectively. The minimum quantity of applied chlorin was at the rate of 3.2 and the maximum 6.3 parts per million. By reference to the results tabulated in Table No. 5, it appears that none of the samples on the three tests were found to contain acid forming colonies on lactose azolitmin agar. The removal of coli-like organisms was practically 100 per cent. These analyses are averages of six samples collected at hourly intervals and plated in duplicate and, therefore, they represent averages of 36 samples with one cubic centimeter examined in each case.

Accompanying the complete removal of coli-like organisms, the treatment with chlorin in quantities as indicated effected a removal of total organisms of 99.8, 99.9 and 99.9 per cent., respectively. The effluent under treatment was substantially of a similar organic character to that found during the copper experiments, January 29th to 31st, 1907. The temperature of the effluent was practically at the maximum density of 4 degrees Centigrade. In reviewing the results it is interesting to note the increase in dissolved oxygen, presumably arising from the liberation of oxygen from the calcium hypochlorite. It should further be noted that in practically all instances by means of the iodo starch tests, residual chloride was detected at the weir after a storage of about three hours.

The hypochlorite solution was tested twice during each six hour run and was found to be practically constant. The solution flowed from the storage tanks at the rate of 0.75 gallon per minute. Changes in the concentration of the disinfectant were made by increasing the concentration of the hypochlorite solution.

TABLE NO. 5.

Volume of Flow, Temperature, Organic and Suspended Matters, and Efficiency of Calcium Hypochlorite Applied to Effluent, Lancaster, Ohio.

Date	Available chlorin. Parts per million.			Volume of effluent treated.			Temperature.	
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Air.	Effluent.
1907.				*Gallons.*	*Gallons.*	*Gallons.*	°C.	°C.
Feb. 8	4.0	3.2	3.6	284,800	191,000	208,200	2.0	4.0
13	6.8	4.0	4.3	191,000	117,800	174,600	11.0	4.0
15	4.1	3.7	4.0	102,000	91,200	94,800	.5	5.0

Date.	Parts per million.																			
	Oxygen consumed.		Nitrogen as—								Suspended matter.		Carbonic acid.				Dissolved oxygen.	
			Organic.		Free ammonia.		Nitrites.		Nitrates.				Free.		Half bound.			
	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Total.	Volatile.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.
1907.																		
Feb. 8	15	13	1.9	....	6.0	5.0	1.20	0.70	2.0	3.0	5	0	20	16	22	21	9.8	11.5
13	16	24	1.7	....	11.0	10.0	1.80	0.90	3.0	3.0	5	0	24	15	33	21	9.6	11.6
15	15	15	.....	....	10.0	8.0	1.60	1.40	3.6	3.0	16	0	30	20	30	27	8.8	7.3

Date.	Putrescibility.	Bacteria per cubic centimeter						Bacterial removal.			Per cent positive with test for *B. coli.*	
		20° C.		37° C.					37° C.			
				Total count.		Red colonies.						
		Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	20° C.	Total colonies.	Acid colonies.	Untreated effluent.	Treated effluent.
1907.								*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Feb. 8	0	100,000	150	15,000	48	140	0	99.8	99.7	100	43	.....
13	0	105,000	120	11,000	45	1,500	3	99.9	99.6	100	66	.....
15	0	192,500	140	15,000	55	870	0	99.9	99.6	100	60	.....

Costs. The cost of constructing a plant for treating the sand filter effluent at the Boys' Industrial School with chlorin may be taken at $92, substantially the same plant could be used as in the case of treatment with copper sulphate.

The estimated cost of chemical is based upon bleaching powder containing 25 per cent. available chlorin and costing 2½ cents per pound. The cost per annum, applying 4 parts per million available chlorin to a sand filter effluent flow of 160,000 gallons, would be about $924, including labor. The daily quantity of chloride of lime required on this basis would be 21.3 pounds, and would cost about 53 cents.

7,770 lbs. bleaching powder, 25 per cent available chlorine at 2½ cents per pound	$194 25
Labor, one man, 365 days, at $2.00 per day	730 00
	$924 25

Capitalized at 5 per cent. the investment would be $18,500.

MARION.

Experiments at Marion, Ohio, followed those at Lancaster, and consisted of 15 runs from March 21, to May 17, 1907. Conditions were practically the same as in the copper experiments, but the rate of flow of disinfectant solution was increased to 3 gallons per minute. Chemical and bacterial studies were carried out as before and in addition careful tests were made for the presence of residual chlorin and in the latter part of the test there were determined the total numbers of coli in the untreated and treated effluents using the dilution method and bile broth[15] instead of the ordinary fermentation tube media. At Marion, the plant is so designed that it is possible to divert into the effluent sewer untreated septic sewage, the effluent from the contact filters and that from the sand filters and hence it was possible to study the three types of sewage effluent each of different degrees of organic purity and stability as regards a tendency to putrefaction.

Disinfection of the Effluent of the Sand Filters. Three experiments were made with the effluent of the sand filters on March 21, 22 and 26, 1907. The rates of flow which ranged from 284,000 to 876,000, averaged 686,000, 640,000 and 525,000 gallons respectively. The quantity of applied chlorin on the three runs averaged 3.8, 3.0 and 1.5 parts per million.

The effluent from the sand filters was non-putrescible during these tests and contained about 10 parts per million of nitrogen as nitrates, 3.5 organic nitrogen and only 1.0 part of nitrogen as free ammonia. The effluent was low in suspended matter and was at all times well oxygenated.

The total bacteria ranged from 49,000 to 70,000 and the colonies developing on lactose azolitmin agar at 37 deg. C. ranged from 7,000 to 20,000; the acid forming colonies from 800 to 4,000 per cubic centimeter.

The effect of the applied chlorin on the first two runs was the removal of 98.8 and 99.7 per cent. of total bacteria, 98.5 and 99.1 per cent. of colonies developing on lactose azolitmin agar at 37 degrees C. and 100 per cent. of acid forming colonies. On the third test, when the concentration of chlorin was only 1.5 parts per million the removal of bacteria was not so high. Even on the third run, only one red colony developed and this by *full determinative tests* was found to be *Bacillus coli.*

In addition to the enumeration of the acid forming colonies, as already mentioned, further data were obtained as to the colon content of the treated effluent by means of the dilution method, using fermentation tubes supplemented by determinative tests. This method applied to the treated effluent in the case of the three runs under discussion indicated the range of *B. coli* in the untreated effluent to be, respectively, 1,000, 2,000 and 2,000 per cubic centimeter. In the case of the treated effluent, however, this organism was not found in one cubic centimeter. In the third run, however, with a chlorin concentration of only 1.5 parts per million, as before stated, *B. coli* was detected in one cubic centimeter.

At 15-minute intervals during these tests the presence of residual chlorin was determined at the weir in the effluent sewer and at the outlet into Rock Swale Creek. The results of these tests in the case of the sand filter effluent were always negative.

[15] Jackson, D. D. "A New Solution for the Presumptive Test for Bacillus coli." Biological Studies by the Pupils of William Thompson Sedgwick, pp. 292-299, Boston, 1906.

Disinfection of the Effluent of the Contact Filters. Chlorin treatment of the effluent of the contact filters was next studied. This effluent contained organic matter of a more putrescible character than did the sand filter effluent. The average quantity of chlorin on the three days the tests were made was 2.9, 5.0 and 4.4 parts per million. The quantity applied ranged from a minimum of 1.7 to a maximum of 14.5 on the first run; on the second run from a minimum of 2.6 to a maximum of 20.4; and on the third, from a minimum of 2.0 to a maximum of 31.8 parts per million. There was a great variation in the actual concentration of chlorin during these runs due to the nature of the fill-and-draw method of operating the filters since the quantity of sewage discharged from the filter depends upon the volume of sewage contained in the voids. At the end of a discharge the rate is very low and during such periods, of course, the strength of the applied chemical was greatly increased. In this connection, the following tabulation of weir readings of one run with the contact filter effluent will be of interest as illustrating the fluctuation in the volume of the effluent to be treated. In the case of contact filter effluents it is necessary to apply chlorin sufficient for disinfection at the maximum rate of discharge, but, of course, where possible, storage facilities should be provided in order to permit a fairly constant rate of flow of the effluent.

TABLE NO. 6.

Rates of Flow of Contact Filter Effluent, Marion, March 28, 1907, Based upon a Constant Flow for 24 Hours.

Hour.	Rate of Flow, Gallons per 24 Hours.
10:30 A. M.	1,312,800
10:45 "	1,312,800
11:00 "	316,000
11:15 "	1,085,600
11:30 "	685,900
11:45 "	1,444,800
12:00 "	926,300
12:15 P. M.	525,100
12:30 "	778,800
12:45 "	828,900
1:00 "	926,300
1:15 "	778,800
1:30 "	216,500
1:45 "	876,200
2:00 "	469,000
2:15 "	1,253,600
2:30 "	828,900
2:45 "	155,500
3:00 "	1,085,600
3:15 "	525,100
3:30 "	1,032,500

The organic content of the contact filter effluent was somewhat greater than that of the sand filters, and there was less nitrification. The suspended matter was low and ranged from 4 to 8 parts per million. On the last two runs the contact filter effluents were putrescible and in general the effluent was much less purified than the sand filter effluents previously studied. The bacterial content of the contact filter effluents ranged in total bacteria from 67,000 to 500,000 per cubic centimeter. The total number of colonies which developed on lactose

azolitmin agar incubated at 37 degrees C. ranged from 73,000 to 163,000 and the acid forming colonies from 10,000 to 21,000 per cubic centimeter.

The effect of the applied chlorin on the chemical composition of the effluent was a slight increase in free carbonic acid and a decided increase in dissolved oxygen. There was also some oxidation of organic matter as indicated by an increase in the quantity of nitrites.

The average quantity of chlorin on the first run, 2.9 parts per million removed 97.8 of the total organisms. The tests for *B. coli* by the dilution method indicated that the contact filter effluent contained about 20,000 *B. coli* per cubic centimeter, but that after treatment these organisms could not be detected in 0.5 cubic centimeter of the effluent.

In the second run with an average chlorine application of 5.0 parts per million the reduction of total organisms was 97.6 per cent., that of colonies developing at 37 degrees C., on lactose azolitmin agar was 99.5 per cent., that of acid forming colonies was 100 per cent. Further *B. coli* were not found in 0.5 cubic centimeter of the treated effluent, while in the untreated effluent they averaged 15,000 per cubic centimeter. The total organisms in the treated effluent were 1,600, and the total development at 37 degrees C. was 370 per cubic centimeter. No red colonies were found during this run.

On the third run, with an average applied chlorin of 4.4 parts per million, the 500,000 bacteria in the untreated effluent were reduced to 800 and the development at 37 degrees C. on lactose azolitmin agar was only 400 against 163,000 in the untreated effluent. The red colonies developing in the case of the untreated effluent were 21,000 per cubic centimeter and in the treated effluent were found to the number of 3. The tests by the dilution method, however, indicated that *B. coli* usually was not present in 1 cubic centimeter, although found in the untreated effluent approximately 20,000 per cubic centimeter. The percentages of removal of total bacteria, colonies developing at 37 degrees C. on lactose-azolitmin agar, and red colonies were, respectively, 99.8, 99.4 and 99.9.

The tests for residual chlorin in the treated effluent made, as before stated, in the manhole in the effluent sewer and at the cofferdam, were always negative at the latter point. In the case of the runs on March 28 and 29, chlorin was detected neither at the weir in the sewer manhole nor at the cofferdam. In the run on April 3, however, at the weir in the manhole, out of 21 observations carried out at 15-minute intervals chlorin was detected in 12 cases or 57 per cent. of the time; tests at the cofferdam were always negative. The contact period at the weir was about one-half hour.

Disinfection of Septic Tank Effluents. Following the experiments with contact filter effluents there were made nine runs during which the septic effluent was diverted to the effluent sewer. In the first three runs, the quantity of applied chlorin ranged from 4.3 to 7.6 parts per million. This quantity of chlorin did not effect a material removal of either total bacteria or fermenting organisms and as indicated by the data tabulated in Table No. 7 the total bacteria in the treated effluent ranged from 400,000 to 1,100,000 per cubic centimeter, a removal of from 36 to 88 per cent. At the highest concentration studied, the removal of bacteria developing at 37 degrees C. on lactose azolitmin agar was only 59 per cent. On this run, the acid formers were reduced from 100,000 to 51,000 per cubic centimeter an average reduction of 49 per cent. Indications from these three experiments were that concentrations of chlorin from 4.3 to 7.6 parts per million do not afford so complete a removal of bacteria as is desirable. In all cases during these three runs no residual chlorin could be detected in the treated effluent

TABLE NO. 7.

Volume of Flow, Temperature, Organic and Suspended Matter, and Efficiency of Calcium Hypochlorite Applied to Sand and Contact Filter Effluents and to Septic Sewage, Respectively, Marion, Ohio.

Date.	Source.	Available chlorin. Parts per million.			Volume of effluent treated.			Temperature.	
		Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Air.	Effluent.
1907.					*Gallons.*	*Gallons.*	*Gallons.*	*°C.*	*°C.*
Mar. 21	Sand effluent.....	4.9	3.3	3.8	779,000	525,000	686,000	19.0	9.2
22	Sand effluent.....	4.1	2.2	3.0	876,000	469,000	640,000	26.0	11.3
26	Sand effluent.....	2.8	.96	1.5	829,000	284,000	525,000	25.0	12.0
28	Contact effluent.....	14.5	1.7	2.9	1,313,000	156,000	779,000	19.0	11.5
29	Contact effluent.....	20.4	2.6	5.03	1,446,000	186,000	755,000	21.5	11.5
Apr. 3	Contact effluent.....	31.8	2.0	4.4	1,143,000	77,000	539,000	19.0	10.6
11	Septic effluent.....	4.3	3.7	4.3	686,000	596,000	596,000	2.5	10.5
12	Septic effluent.....	6.2	5.8	6.2	640,000	596,000	596,000	3.0	11.0
15	Septic effluent.....	8.2	7.0	7.6	640,000	553,000	596,000	8.0	5.6

Date.	Source.	Parts per million.																			
		Oxygen consumed.		Nitrogen as —								Susp. matter.		Carbonic acid.				Dissolved oxygen.	
				Organic.		Free ammonia.		Nitrites.		Nitrates.				Free.		Half bound.			
		Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Total.	Volatile.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.
1907.																			
Mar. 21	Sand effluent.	17	16	3.3	....	0.6	0.7	1.70	1.60	12.0	12.0	2	..	28	21	116	115	4.8	5.8
22	Sand effluent.	16	15	3.2	....	0.7	0.8	1.60	1.60	11.0	11.0	2	..	36	26	132	129	5.0	5.5
26	Sand effluent.	17	17	3.9	....	2.0	1.6	0.60	0.80	9.0	8.6	3	..	34	26	163	163	5.9	7.2
28	Contact effluent	12	12	0.9	....	7.0	7.0	0.56	1.20	10.4	9.6	5	..	19	15	176	163	0.0	0.0
29	Contact effluent	15	12	1.3	....	6.6	6.6	0.80	0.60	7.0	6.0	4	..	25	24	185	180	3.1	4.0
Apr. 3	Contact effluent	26	23	3.6	....	6.0	9.0	0.20	0.19	3.0	1.6	8	..	42	39	176	176	1.5	5.4
11	Septic efflu'nt.	40	42	14.2	....	20.0	20.0	0.06	0.00	0.0	0.2	34	28	25	15	....	....	0.3	2.8
12	Septic efflu'nt.	50	48	14.2	....	20.0	22.0	0.30	0.20	0.0	0.0	32	27	39	20	....	....	1.7	3.0
15	Septic efflu'nt.	48	....	14.0	....	35.0	30.0	0.00	0.00	0.0	0.0	36	30	56	41	250	....	0.0	0.0

TABLE NO. 7 — Concluded.

Date.	Source.	Putrescibility.	Bacteria per cubic centimeter.						Bacterial removal.			*B. coli* per cubic centimeter.	
			20° C.		37° C.					37° C.			
					Total count.		Red colonies.						
			Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	20° C.	Total colonies.	Acid colonies.	Untreated effluent.	Treated effluent.
1907.									*P.ct.*	*P.c.*	*P.c.*		
Mar. 21	Sand effluent..	0	49,000	570	9,800	150	1,300	0	98.8	98.5	100	1,000	Not in 1 c. c.
22	Sand effluent..	0	56,000	140	7,000	60	800	0	99.7	99.1	100	2,000	Not in 1 c. c.
26	Sand effluent..	0	70,000	4,000	20,000	160	4,000	1	94.3	99.2	99.9	2,000	Present in 1 c. c.
28	Contact effluent.	0	110,000	2,500	.....	.....	.....	.....	97.8	....	....	20,000	Not in 0.5 c. c.
29	Contact effluent.	+	65,000	1,600	73,000	370	10,000	0	97.6	99.5	100	15,000	Not in 0.5 c. c.
Apr. 8	Contact effluent.	+	500,000	800	160,000	400	21,000	3	99.8	99.4	99.9	20,000	Not in 1 c. c.
11	Septic effluent.	+	850,000	1,100,000	1,200,000	240,000	55,000	7,400	— 130	80.0	87.0	.....	.....
12	Septic effluent.	+	4,400,000	550,000	850,000	260,000	60,000	15,000	88.0	70.0	75.0	.....	.....
15	Septic effluent.	+	600,000	400,000	450,000	190,000	100,000	51,000	36.0	59.0	49.0	.....	.....

Following the experiments just discussed in which the quantity of applied chlorin ranged from 4.3 to a maximum of 7.6 parts per million, an effort was made to learn the efficiency of greatly increased quantities of chlorin. Such information would appear to be of considerable importance in connection with the disinfection of hospital sewages at times of epidemics in cases where sedimentation alone was the only permanent available means of treating the crude sewage. To this end there was made at Marion six experiments on the chlorin treatment of the septic sewage the amount of applied chemical ranging from an average of 7.3 to a maximum average of 48.5 parts per million; the experiments at these higher concentrations were conducted substantially as those already discussed.

By reference to Table No. 8 it will be noted that about 25 parts per million of applied available chlorin were sufficient to remove a substantial proportion of coli-like organisms, although a complete removal of *B. coli* was not accomplished. In the case of the fourth experiment at an approximate concentration of 25 parts per million, with a sewage flow averaging about 650,000 gallons, the total bacteria in the untreated sewage averaged 800,000 and were reduced to 62,000. The number of colonies developing on lactose-azolitmin agar at 37 degrees C. was 200,000 per cubic centimeter and was reduced to 35,000. The *B. coli* on this test as shown by the bile broth fermentation tube method were 15,000 in the untreated sewage and 50 after chlorin treatment. The reduction with respect to *B. coli* was 99.3 per cent.

In the subsequent runs in which the concentration of the applied available chlorin was increased to a maximum average of 48.5 parts per million, the removal of *B. coli* was found only slightly greater than in the case of the application of 25 parts per million available chlorin, the numbers of *B. coli* remaining in the treated sewage ranged from 20 to 200 per cubic centimeter. In this connection it should be noted that the suspended matter in the septic effluent increased considerably and probably in a large part explained the low removals obtained with the increased quantity of applied chemical. Observations made during the experiments at Marion emphasizes the great effect of the periodic discharge of a septic effluent charged heavily with suspended matters. At such times, no doubt, the absorption of chlorin in very great and presumably the organic matter in suspension in the septic effluent destroys a considerable part of the added disinfectant.

The effect of the different concentrations of applied chlorin in the case of the Marion septic sewage is noticeably erratic in this regard. The conclusion seems tenable that these irregularities are in large part at least to be attributed to the presence in the septic effluent of large masses of suspended matter. On this account, available evidence seems to point to the strong advisability of thoroughly settling a septic tank effluent in the case of contemplated chlorin treatment except, of course, in those special cases where the flexibility of the design of the septic tanks is such that a well settled septic effluent is normally obtained at all times.

TABLE NO. 8.

Volume of Flow, Temperature, Organic and Suspended Matter, and Efficiency of Calcium Hypochlorite Applied to Septic Sewage, Marion, Ohio.

Date.	Available chlorin parts per million.			Volume of effluent treated.			Temperature.	
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Air.	Effluent.
1907.				*Gallons.*	*Gallons.*	*Gallons.*	°C.	°C.
May 3	7.5	7.0	7.3	779,000	732,000	755,000	16.0	10.5
6	19.6	17.0	18.3	779,000	676,000	709,000	11.0	10.5
10	23.6	22.2	22.9	779,000	732,000	732,000	13.5	10.5
13	27.3	22.2	24.8	732,000	596,000	647,000	27.0	11.0
15	34.6	27.2	30.6	779,000	640,000	698,000	15.5	11.5
17	52.1	44.8	48.5	640,000	553,000	600,000	22.0	11.5

Date.	Parts per million.																	
	Oxygen consumed.	Nitrogen as—								Suspended matter.		Carbonic acid.				Dissolved oxygen.	
		Organic.	Free ammonia.		Nitrites.		Nitrates.				Free.		Half bound.			
			Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Total	Volatile.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.
1907.																
May 3	46	8.0	16.0	16.0	0.50	0.50	0.0	0.0	44	34	59	46	181	181	0.0	2.8*
6	51	7.6	18.0	20.0	0.00	0.10	0.0	0.0	47	37	51	43	180	176	0.0	3.1
10	36	6.0	14.0	12.0	0.60	0.50	0.0	0.0	30	14	60	44	171	167	1.2	4.8
13	29	4.0	20.0	16.0	0.20	0.20	0.0	0.0	104	86	62	38	184	183	0.0	3.9
15	42	5.6	20.0	20.0	0.00	0.00	0.0	0.0	77	68	53	39	188	186	0.0	2.3
17	43	4.0	20.0	20.0	0.00	0.06	0.0	0.0	79	69	60	35	197	194	0.0	3.4

TABLE NO. 8 — Concluded.

	Putrescibility.	Bacteria per cubic centimeter.						*B. coli* per cubic centimeter, bile medium.		Bacterial removal.			
		20° C.		37° C.						37° C.			
				Total count.		Red colonies.							
		Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	Untreated effluent.	Treated effluent.	20° C.	Total colonies.	Acid colonies.	*B. coli*, by bile.
1907.										*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
May 8	+	250,000	290,000	1,000,000	470,000	55,000	35,000	.....	.....	—16	53	36	.....
6	+	1,200,000	950,000	850,000	360,000	45,000	28,000	50,000	10,000	20.0	57.6	38	80.0
10	+	1,700,000	2,500	120,000	800	50,000	0	30,000	100	99.8	99.3	100	99.8
13	+	800,000	62,000	200,000	35,000	48,000	.....	15,000	80	92.2	82.5	.....	99.3
15	+	750,000	290,000	.....	.....	.....	.....	30,000	150	61.3	.....	.....	99.5
17	+	750,000	72,000	.....	.....	.....	.....	30,000	35	90.4	.....	.....	99.8

Costs. The cost of constructing a plant for treating the several effluents studied at Marion, may be taken as $151 exclusive of arrangements for supplying water to dissolve the chloride of lime. This estimate allows for continuous treatment at a rate of flow of 600,000 gallons in 24 hours.

Bleaching powder containing 25 per cent available chlorine at two and one-half cents per pound has been used as the basis of the following estimates.

The cost of applying 4.0 parts per million of available chlorin to the sand filter effluent using 80 pounds of hypochlorite daily would be $730 annually. The total annual cost including labor but exclusive of the cost of supply water for preparing the chlorin solution would be about $1.620, on the basis of an effluent flow of 600,000 gallons daily. Capitalized at 5 per cent this would represent an investment of $29,000.

The cost of applying 5.0 parts per million of available chlorin to the contact filter effluent, would be about $2.50 per day requiring 100 pounds of chemical. The total annual cost, including labor, but exclusive of the cost of pumping or otherwise supplying the water for dissolving the germicide, would be about $1,825. Capitalized at 5 per cent the cost of treatment per annum would require an investment of $36,500.

Assuming 25 parts per million as a fair average figure for the disinfection of the septic effluent, provided the same is at all times free from abnormal quantities of suspended matters, the daily cost for chemical would be about $12.50 requiring daily 500 pounds of chloride of lime containing 25 per cent available chlorin. The total annual cost including labor would be about $5,300. Capitalized at 5 per cent, the investment represented would be about $106,000.

CHLORIN ABSORPTION EXPERIMENTS.

In connection with studies made at Guildford regarding the treatment of sewage effluents with chlorin, Doctor Rideal concluded that there was a fairly definite relation between the chlorin consuming power of the effluent and the oxygen consumed resulting from a five-minute boiling test.[16] He states that the

[16] Rideal, Samuel. On the Sterilization of Effluents, etc. Jour. of the Royal Sanitary Institute, vol. 26, No. 7, pp. 378–406; discussion, pp. 407–416. London, August, 1905. Oxychloride Sewage Purification. Sanitary Record and Journal of Sanitary and Municipal Engineering, vol. 34, pp. 329–332. London, October 6, 1904. Sewage and Bacterial Purification of Sewage. 3d ed., London and New York, 1906, p. 186.

ratio chlorin consumed to oxygen consumed is practically a constant, that chlorin in excess of the quantity absorbed is required for disinfection, and that the quantity of chlorin necessary for treatment can consequently be computed by multiplying the oxygen consumed by the factor 1.7.

In view of the importance attached to chlorine absorption by previous investigations and the fact that a fixed relation between the chlorin and the oxygen consumed, respectively, would be of marked value in the practical control of disinfection with chlorin, it was decided to make certain studies to inquire into the chlorin-oxygen relation for conditions at Lancaster. Especially was this important since a complete removal of *B. coli* was obtained by the use of slightly less than 5 parts chlorin per million, and also since there was noted the presence of residual chlorin after a three-hour storage of the treated effluent. Taking into consideration the average oxygen consumed of the treated effluent, the indications were that the relation between the chlorin and the oxygen consumed is somewhat different from that suggested by Doctor Rideal.

Lancaster Experiments.

The Lancaster experiments leading to the establishment of a ratio between the chlorin and the oxygen consumed, consisted in a series of tests, wherein chlorin at two concentrations, namely 500 and 100 parts per million, was added to the sewage effluent and also to the crude sewage, each of which were studied in dilutions wherein the percentage of effluent or sewage ranged from 100 to 0. The chlorin was, of course, added in the cold and after a five-minute period of contact the residual chlorin was determined by titration with N/10 arsenious acid. A contact period of two hours was also studied to learn the effect of time on the absorption of the chlorin. To obtain the relation between the chlorin consumed and the oxygen consumed, the latter was determined in the case of all samples by the standard method of boiling for exactly five minutes with an excess of permanganate in acid solution.

A second method of studying chlorin absorption phenomena was carried out by adding to a known volume of the sewage effluent different quantities of chlorin, ranging from 2 to 75 parts per million. After the end of 0.25, 0.50, 0.75, 1.00, 1.50. 2.00, 2.50, 3.00 and 4.00 hours, the presence of residual chlorin was determined by means of iodo starch paper.

Results of Experiments. Speaking generally, the results of the chlorine consumed experiments carried out at Lancaster were not so concordant as desired. In view of the high absorption, moreover, it was difficult to account for the presence of residual chlorin after three hours' storage when only five parts of chlorin per million was being added to the sewage effluent. However, this may be, the results indicated that there was no definite relation between the oxygen consumed and the chlorin consumed and that notwithstanding the high chlorin absorptive capabilities of the sewage effluent, the addition of 5 parts per million of chlorin sufficed to destroy practically 100 per cent of the colon organisms, indicating that oxygen liberated from the decomposing chloride of lime accomplished disinfection, although the organic character of the effluent was such that it could absorb many times the quantity of chlorin applied. In Tables Nos. 9 to 15, inclusive, are listed the summarized data obtained at Lancaster wherein is compared the chlorin consumed and the oxygen consumed of the crude sewage and the sewage effluent, respectively. Referring to Tables Nos. 9 to 11, it will be noted that these results strongly indicate that there is no definite relation between the chlorin consuming power of the effluent and the oxygen consumed by the five-minute boiling test. There will also be observed the wide range in the quantity of chlorin absorbed by the effluent. The increase after a two and four hour contact, respectively, is also worthy of note. Comparing Tables Nos. 14

and 15, there is obtained a rough indication of the effect of the concentration of chlorin upon the absorptive power of the effluent. Speaking generally, it may be said that the indications point to an increased absorption as the concentration of applied chlorin increases.[17] As already mentioned, these data are too ragged to draw definite conclusions.

Similar conclusions may be drawn from a study of Tables Nos. 12 and 13 in which are listed the results of the application of chlorin to sewage variously diluted. These results indicate also that apparently no definite relation exists between the chlorin consuming power of the treated liquid and the oxygen consumed by permanganate. The data although too inconsistent for definite conclusions, indicate that the relation between the chlorin consumed and the oxygen consumed is very much greater than the figure 1.7, as stated by Doctor Rideal and that the quantity of chlorin absorbed very materially increases as the organic content of the treated liquid increases, and also as the strength of applied chlorin increases.

TABLE NO. 9.

Relative Absorption of Chlorin and Oxygen by the Lancaster Sand Filter Effluent With Various Quantities of Tap Water. Chlorin Concentration of 500 Parts to the Million.

Per cent of effluent.	Five Minutes' Contact.			Five Minutes' Contact.		
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
100	16	114	7.1	9.3	43	4.5
75	12	47	3.9	7.0	50	7.2
50	8	47	5.9	4.7	29	6.2
25	4	47	11.9	3.5	68	19.4
0	0	118	118.0	0.0	3	3.0

TABLE NO. 10.

Relative Absorption of Chlorin and Oxygen by the Lancaster Sand Filter Effluent With Various Quantities of Tap Water. Chlorin Concentration of 500 Parts to the Million.

Per cent of effluent.	Five Minutes' Contact.			Two Hours' Contact.		
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
100	7.3	122	17.0	7.3	93	12.8
75	5.7	.....	.....	5.7	77	13.6
50	3.7	13	3.5	3.7	9	2.4
25	1.9	52	27.5	1.9	55	29.0
0	0.0	14	14.0	0.0	26	14.0

[17] This latter fact is noted by Rideal.

TABLE NO. 11.

Relative Absorption of Chlorin and Oxygen by the Lancaster Sand Filter Effluent With Various Quantities of Tap Water. Chlorin Concentration of 100 Parts to the Million.

Per cent of effluent.	Five Minutes' Contact.			Five Minutes' Contact.		
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
100	5.6	53.0	9.5	5.5	75.0	13.3
75	4.1	38.0	9.3	4.0	52.0	13.0
50	2.7	14.0	5.1	2.6	43.0	16.3
25	1.4	9.2	6.6	1.3	21.0	16.0
0	0.0	8.8	3.8	0.0	3.5	3.5

TABLE NO. 12.

Chlorin Absorbed by Crude Sewage Diluted with Different Quantities of Tap Water. Chlorin Concentration of 500 Parts to the Million.

Per cent of sewage.	Five Minutes' Contact.			Two Hours' Contact.		
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
100	166	266	1.60	166	390	2.34
75	123	202	1.64	123	354	2.69
50	83	174	2.09	83	238	2.87
25	42	68	1.62	42	102	2.42
0	0	118	118.00	0	118	118.00

TABLE NO. 13.

Chlorin Absorbed by Crude Sewage Diluted with Different Quantities of Tap Water. Chlorin Concentration of 500 Parts to the Million.

Per cent of sewage.	Five Minutes' Contact.			Two Hours' Contact.		
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
100	46.0	245	5.3	46.0	327	7.1
75	24.0	32	1.3	24.0	132	5.5
50	13.0	122	9.4	13.0	167	12.8
25	6.5	72	9.0	6.5	114	17.5
0	0.0	14	14.0	0.0	26	26.0

Results of Chlorin Absorption Studies.

The chlorin absorption studies referred to above, indicated that chlorin up to 7.5 parts per million would be absorbed from the sewage effluent in about 0.75 hour. Indications were also at hand that chlorine in concentrations of 10 parts and over would be detected in the treated effluent at the end of four hours. Additional experiments showed entirely different results, however, in one instance indicating that a chlorine concentration of 75 parts per million could not be detected at the end of one hour. Data illustrating these points are listed in tables Nos. 14 and 15.

TABLE NO. 14.

Chlorin Absorption When Constant Volumes of Effluent are Treated with Different Quantities of Chlorin for Different Periods of Contact. Volume of Effluent Treated, 500 Cubic Centimeters.

Residual chlorin present indicated by +; absent, by 0.

Applied chlorin (parts per mill'n.)	Elapsed Time (Hours).								
	0.25.	0.50.	0.75.	1.00.	1.50.	2.00.	2.50.	3.00.	4.00.
2.0	0	0	0	0	0	0	0	0	0
4.0	0	0	0	0	0	0	0	0	0
5.0	+	0	0	0	0	0	0	0	0
7.5	+	+	0	0	0	0	0	0	0
10.0	+	+	+	+	+	+	+	+	+
20.0	+	+	+	+	+	+	+	+	+
50.0	+	+	+	+	+	+	+	+	+
75.0	+	+	+	+	+	0	+	0	0

TABLE NO. 15.

Chlorin Absorption When Constant Volumes of Effluent are Treated with Different Quantities of Chlorin for Different Periods of Contact. Volume of Effluent Treated, 500 Cubic Centimeters.

Residual chlorin present indicated by +; absent, by 0.

Applied chlorin (parts per mill'n.)	Elapsed Time (Hours).								
	0.25.	0.50.	0.75.	1.00.	1.50.	2.00.	2.50.	3.00.	4.00.
2.0	0	0	0	0	0	0	0	0	0
4.0	0	0	0	0	0	0	0	0	0
5.0	+	+	0	0	0	0	0	0	0
7.5	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	+	+	+	+
20.0	+	+	+	+	+	+	+	+	+
50.0	+	+	+	+	+	+	+	+	+
75.0	+	+	+	0	0	0	0	0	0

Marion Experiments.

In continuing these studies at Marion, there were made 48 separate experiments using, respectively, different dilutions with tap water, sand filter effluent, contact filter effluent, septic sewage and crude sewage.

The procedure employed in the experiments were as follows: A mixture of the effluent under treatment was prepared, diluted with 0, 25, 50, 75 and 100 per cent of tap water, respectively. To the effluent thus diluted in volumes of one liter placed in separate containers, there was added in the case of each solution listed above, chlorin to the extent of 50, 100, 250 and 500 parts per million, respectively. The quantity of chlorin was carefully adjusted by means of a N/100 arsenious acid solution checked by titration with N/100 iodine, using iodo starch paper only to indicate the excess of arsenious acid. After a period of contact of five minutes, the residual chlorin was determined in all cases by titration with arsenious acid; the same data were again determined after a contact period of two hours. In each experiment, the oxygen consumed by the five minute boiling method over a free flame was determined in the case of each dilution with tap water. Each of these series of experiments was repeated three times. Hence for each dilution with tap water there were made twelve separate chlorin consumed experiments at four different concentrations of applied chlorin.

Several absorption tests followed these experiments and were carried out with a view to comparing the actual chlorin consuming power to the oxygen consumed for different concentrations of chlorin and in the case of the four different sewage effluents available at this plant. The results obtained were similar to those at Lancaster.

Discussion of Results. Generally speaking, the results of the somewhat exhaustive study of these chlorin absorption phenomena were very much more consistent than the few data obtained at Lancaster. The work was carried out in a very systematic manner, better facilities were at hand for rapid operation, and consequently the results are to be considered much more reliable.

In tabulating the data, they are presented below in two different ways, the first intended to show the effect of the concentration of the applied chlorin upon the amount of absorption, and the chlorin-oxygen consumed ratio, and also, the effect of the period of contact upon these same data. To this end, therefore, the four kinds of sewagic liquid studied are listed in Tables Nos. 16 to 31, inclusive, showing the average results for the different dilutions with tap water, and showing the effect of the time factor and the strength of the applied chlorin upon the chlorin absorption and the chlorin consumed — oxygen consumed ratio.

In the second set of Tables Nos. 32 to 39 inclusive, are listed the average results of the forty-eight experiments arranged with a view to indicate the effect of organic matter at different concentrations of applied chlorin, the table being arranged as before with respect to the degree of dilution of the sewage under study.

From the summarized results of the chlorin absorption studies tabulated below, there may be drawn the following provisional conclusions.

1. The ratio chlorin consumed to oxygen consumed in a five minute period of contact bears no constant relation to the oxygen consumed by the five minute boiling method.

2. The concentration of applied chlorin affects the quantity of chlorin absorbed, the absorption at a concentration of 100 parts per million being fully double that at 50 parts per million.

3. Increasing concentrations of chlorin up to 250 parts per million, increase the quantity of absorbed chlorin very materially, but above this figure there appears

to be very little increased absorption even with a chlorin concentration of 500 parts per million.

4. Increasing the period of contact to two hours effects but little increase in the chlorin consumed-oxygen consumed ratio, except for the higher chlorin concentration of from 250 to 500 parts per million.

5. The actual quantity of chlorin absorbed in 5 minutes by the several liquids tested, under concentrations of chlorin of 50, 100, 250 and 500 parts per million, ranged as follows:

Crude sewage	24 to 148
Septic sewage	41 to 160
Contact filter effluent	42 to 80
Sand filter effluent	33 to 68

6. The absorption of chlorin apparently is largely dependent upon the organic content of the liquid treated, increasing materially as the oxygen consumed of the effluent increases.

7. For the same concentration of applied chlorin, the ratio between chlorin consumed and the oxygen consumed appears to increase as the organic matters decrease.

8. The readily oxidizable matter in the septic sewage studied apparently caused a rapid absorption of chlorin, increasing the chlorin-oxygen ratio, especially in the case of the lower concentrations of applied chlorin.

TABLE NO. 16.

Relative Absorption of Chlorin and Oxygen by Contact Effluent.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
50	94	34	0.36	36	0.38
100	94	60	0.64	63	0.67
250	94	144	1.50	178	1.90
500	94	148	1.60	209	2.20

TABLE NO. 17.

Relative Absorption of Chlorin and Oxygen by Septic Effluent.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million).	Ratio of chlorin to oxygen.
50	49	41	0.0	42	0.9
100	49	66	1.3	73	1.5
250	49	163	3.3	179	3.7
500	49	160	2.6	204	3.3

TABLE NO. 18.

Relative Absorption of Chlorin and Oxygen by Contact Effluent.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
49	24	42	1.7	42	1.7
98	24	81	3.3	85	3.5
244	24	84	3.5	98	4.1
488	24	80	3.3	95	4.0

TABLE NO. 19.

Relative Absorption of Chlorin and Oxygen by Sand-Filter Effluent.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
50	19	33	1.6	40	2.1
100	19	54	2.8	60	3.2
250	19	67	3.5	71	3.7
500	19	68	3.6	80	4.2

TABLE NO. 20.

Relative Absorption of Chlorin and Oxygen by 75 Parts of Crude Sewage Diluted with 25 Parts of Tap Water.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
50	70	33	0.47	35	0.5
100	70	72	1.0	71	1.0
250	70	119	1.7	150	2.1
500	70	107	1.5	166	2.4

TABLE NO. 21.

Relative Absorption of Chlorin and Oxygen by 75 Parts of Septic Effluent Diluted with 25 Parts of Tap Water.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
50	37	36	1.0	40	1.1
100	37	85	2.3	86	2.3
250	37	125	3.4	141	3.8
500	37	123	3.3	173	4.7

TABLE NO. 22.

Relative Absorption of Chlorin and Oxygen by 75 Parts of Contact Effluent Diluted with 25 Parts of Tap Water.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
49	21	39	1.9	40	1.9
98	21	63	3.0	71	3.4
244	21	65	3.1	78	3.7
488	21	60	2.9	74	3.5

TABLE NO. 23.

Relative Absorption of Chlorin and Oxygen by 75 Parts of Sand Filter Effluent Diluted with 25 Parts of Tap Water.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
49	14	28	2.0	33	2.3
97	14	51	3.6	56	4.0
244	14	51	3.6	54	3.9
486	14	53	3.8	63	4.5

TABLE NO. 24.

Relative Absorption of Chlorin and Oxygen by 50 Parts of Crude Sewage Diluted with 50 Parts of Tap Water.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
50	47	29	0.6	30	0.64
100	47	71	1.5	78	1.7
250	47	80	1.7	118	2.5
500	47	83	1.9	112	2.4

TABLE NO. 25.

Relative Absorption of Chlorin and Oxygen by 50 Parts of Septic Effluent Diluted with 50 Parts of Tap Water.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
50	25	35	1.4	39	1.6
100	25	82	3.3	91	3.6
250	25	82	3.3	128	5.1
500	25	81	3.2	117	4.7

TABLE NO. 26.

Relative Absorption of Chlorin and Oxygen by 50 Parts of Contact Effluent Diluted with 50 Parts of Tap Water.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
49	14	35	2.5	36	2.6
98	14	46	3.3	53	3.8
244	14	50	3.6	59	4.2
488	14	37	2.6	53	3.8

TABLE NO. 27.

Relative Absorption of Chlorin and Oxygen by 50 Parts of Sand Filter Effluent Diluted with 50 Parts of Tap Water.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
19	9	29	3.2	34	3.8
97	9	36	4.0	44	4.9
244	9	36	4.0	44	4.9
486	9	43	4.8	49	5.3

TABLE NO. 28.

Relative Absorption of Chlorin and Oxygen by 25 Parts of Crude Sewage Diluted with 75 Parts of Tap Water.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
50	23	36	1.6	40	1.7
100	23	43	1.9	55	2.4
250	23	43	1.9	70	3.0
500	23	28	1.2	59	2.6

TABLE NO. 29.

Relative Absorption of Chlorin and Oxygen by 25 Parts of Septic Effluent Diluted with 75 Parts of Tap Water.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
50	12	41	3.4	48	4.0
100	12	56	4.7	57	4.8
250	12	47	3.9	62	5.2
500	12	48	4.0	72	6.0

TABLE NO. 30.

Relative Absorption of Chlorin and Oxygen by 25 Parts of Contact Effluent Diluted with 75 Parts of Tap Water.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
49	7	25	3.6	28	4.0
98	7	26	3.7	30	4.3
244	7	27	3.9	36	5.1
488	7	18	2.6	31	4.4

TABLE NO. 31.

Relative Absorption of Chlorin and Oxygen by 25 Parts of Sand Filter Effluent Diluted with 75 Parts of Tap Water.

Concentration of chlorin (parts per million.)	Five Minutes' Contact.			Two Hours' Contact.	
	Oxygen consumed (parts per million).	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.	Chlorin consumed (parts per million.)	Ratio of chlorin to oxygen.
49	5	21	4.2	26	5.2
97	5	24	4.8	27	5.4
244	5	27	5.4	24	4.8
486	5	24	4.8	41	8.2

TABLE NO. 32.

Relative Absorption of Chlorin and Oxygen, Showing Especially the Effect of Organic Matter; 100 Parts of Sewage or Effluent; Contact Period, Five Minutes.

Concentration of chlorin (parts per million.)	Oxygen Consumed (Parts Per Million).				Chlorin Consumed (Parts Per Million).				Ratio of Chlorin to Oxygen.			
	Crude sewage.	Septic sewage	Contact filter effluent.	Sand filter effluent	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent	Sand filter effluent.
50	94	49	24	14	34	41	42	.....	0.4	0.9	1.7	.....
100	94	49	24	14	60	66	80	.....	0.6	1.3	3.3	.....
250	94	49	24	14	144	160	84	.....	1.5	3.3	3.5	.....
500	94	49	24	14	148	160	80	.....	1.6	3.6	3.3	.....

TABLE NO. 33.

Relative Absorption of Chlorin and Oxygen, Showing Especially the Effect of Organic Matter; 75 Parts of Sewage or Effluent Diluted with 25 Parts of Tap Water; Contact Period, Five Minutes.

Concentration of chlorin (parts per million.)	Oxygen Consumed (Parts Per Million).				Chlorin Consumed (Parts Per Million).				Ratio of Chlorin to Oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	70	37	21	.....	33	36	39	28	0.47	1.0	1.9	2.0
100	70	37	21	.....	72	85	63	51	1.0	2.3	3.0	3.6
250	70	37	21	.....	119	125	65	51	1.7	3.4	3.1	3.6
500	70	37	21	.....	107	123	60	53	1.5	3.3	2.9	3.8

TABLE NO. 34.

Relative Absorption of Chlorin and Oxygen, Showing Especially the Effect of Organic Matter; 50 Parts of Sewage or Effluent Diluted with 50 Parts of Tap Water; Contact Period, Five Minutes.

Concentration of chlorin (parts per million.)	Oxygen Consumed (Parts Per Million).				Chlorin Consumed (Parts Per Million).				Oxygen. Ratio of Chlorin to			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	47	25	14	9	29	35	35	29	0.6	1.4	2.5	3.2
100	47	25	14	9	71	82	46	36	1.5	3.3	3.3	4.0
250	47	25	14	9	80	82	50	36	1.7	3.3	3.6	4.0
500	47	25	14	9	83	81	37	43	1.8	3.2	2.6	4.8

TABLE NO. 35.

Relative Absorption of Chlorin and Oxygen, Showing Especially the Effect of Organic Matter; 25 Parts of Sewage or Effluent Diluted with 75 Parts of Tap Water; Contact Period, Five Minutes.

Concentration of chlorin (parts per million.)	Oxygen Consumed (Parts Per Million).				Chlorin Consumed Ratio of Chlorin to				Ratio of Chlorin to Oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	23	12	7	5	36	41	25	21	1.6	3.4	3.6	4.2
100	23	12	7	5	43	56	26	24	1.9	4.7	3.7	4.8
250	23	12	7	5	43	47	27	27	1.9	3.9	3.9	5.4
500	23	12	7	5	28	48	18	24	1.2	4.0	2.6	4.8

TABLE NO. 36.

Relative Absorption of Chlorin and Oxygen, Showing Especially the Effect of Organic Matter; 100 Parts of Sewage or Effluent; Contact Period, Two Hours.

Concentration of chlorin (parts per million.)	Oxygen Consumed (Parts Per Million).				Chlorin Consumed (Parts Per Million).				Ratio of Chlorin to Oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	94	49	24	19	36	42	42	40	0.38	0.9	1.7	2.1
100	94	49	24	19	63	73	85	60	0.67	1.5	3.5	3.2
250	94	49	24	19	178	179	98	71	1.9	3.7	4.1	3.7
500	94	49	24	19	209	204	95	80	2.2	3.3	4.0	4.2

TABLE NO. 37.

Relative Absorption of Chlorin and Oxygen, Showing Especially the Effect of Organic Matter; 75 Parts of Sewage or Effluent Diluted with 25 Parts of Tap Water; Contact Period, Two Hours.

Concentration of chlorin (parts per million.)	Oxygen Consumed (Parts Per Million).				Chlorin Consumed (Parts Per Million).				Ratio of Chlorin to Oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	70	37	21	14	35	40	40	33	0.5	1.1	1.9	2.3
100	70	37	21	14	71	86	71	56	1.0	2.3	3.4	4.0
250	70	37	21	14	150	141	78	54	2.1	3.8	3.7	3.9
500	70	37	21	14	166	173	74	63	2.4	4.7	3.5	4.5

TABLE NO. 38.

Relative Absorption of Chlorin and Oxygen, Showing Especially the Effect of Organic Matter; 50 Parts of Sewage or Effluent Diluted with 50 Parts of Tap Water; Contact Period, Two Hours.

Concentration of chlorin (parts per million.)	Oxygen Consumed (Parts Per Million).				Chlorin Consumed (Parts Per Million).				Ratio of Chlorin to Oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	47	25	14	9	30	39	36	34	0.64	1.6	2.6	3.8
100	47	25	14	9	78	91	53	44	1.7	3.6	3.8	4.9
250	47	25	14	9	118	128	59	44	2.5	5.1	4.2	4.9
500	47	25	14	9	112	117	53	49	2.4	4.7	3.8	5.3

TABLE NO. 39.

Relative Asorption of Chlorin and Oxygen, Showing Especially the Effect of Organic Matter; 25 Parts of Sewage or Effluent Diluted with 75 Parts of Tap Water; Contact Period, Two Hours.

Concentration of chlorin (parts per million.)	Oxygen Consumed (Parts Per Million).				Chlorin Consumed (Parts Per Million).				Ratio of Chlorin to Oxygen.			
	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.	Crude sewage.	Septic sewage.	Contact filter effluent.	Sand filter effluent.
50	23	12	7	5	40	48	28	26	1.7	4.0	4.0	5.2
100	23	12	7	5	55	57	30	27	2.4	4.8	4.3	5.4
250	23	12	7	5	70	62	36	24	3.0	5.2	5.1	4.8
500	23	12	7	5	59	72	31	41	2.6	6.0	4.4	8.2

SUMMARY AND CONCLUSIONS.

Although there are many instances when the purification of domestic sewage to a point of ultimate stability is sufficient to correspond to local requirements, yet there are cases where it is desirable to remove from the effluent dangerous disease bacteria, especially where the sewage effluent is discharged into tidal waters used for shellfish culture.

Very satisfactory results were obtained with both copper sulphate and chloride of lime. Copper sulphate appeared the more limited as regards its adaptability to practical conditions in that its efficiency is perhaps more dependent upon a high grade sewage effluent, together with a required storage point of at least three hours; chlorin as bleaching powder, on the other hand, requires less storage and is less susceptible to organic matter.

The indications drawn from these studies were briefly that a sewage effluent (Lancaster 160,000 gallons daily), of a purity equal to that from efficiently operated intermittent sand filters, may be disinfected as regards *B. coli* by the use of 13 parts per million of copper sulphate (108 pounds per million gallons) with a storage of treated effluent of about three hours and at a cost for chemicals of about $6.48 per million gallons. Similar results with chloride of lime required about 4.0 parts per million available chlorin (133 pounds per million gallons bleaching powder containing 25 per cent available chlorin), under one hour's storage at a cost of $3.32 per million gallons.

With less highly purified effluents, greater quantities of copper sulphate were required, 40 parts per million (334 pounds per million gallons), applied to the Westerville continuous contact filter effluent, (41,000 gallons daily) removing, however, about 99.3 per cent of the acid forming colonies under about one hour's storage and at a cost for chemicals of about $20 per million gallons. Chloride of lime, on the other hand, under the application of lesser quantities appeared to be quite efficient for effluents of less stability than those from sand filters, results from the putrescible Marion contact filters showing a removal of 100 per cent of fermenting organisms with the use of 5.0 parts per million of applied chlorin (166 pounds per million gallons, bleaching powder containing 25 per cent available chlorin) at a cost for chemicals of $4.15 per million gallons.

Passing to septic tank effluents, (Marion) the use of as high as 25 parts per million available chlorin (834 pounds per million gallons, bleaching powder

containing 25 per cent available chlorin) at a cost for chemicals of $20.85 per million gallons, removed 99.3 per cent of fermenting organisms, indications being strong that a more thorough settling of the septic effluent and the application of larger quantities of chemical would effectively destroy organisms of the *B. coli* type. The increased cost would, of course, be admissible in cases of epidemics and moreover only under such conditions would there probably ever arise the question of the treatment of a sewage effluent as putrescible and as difficult to disinfect as the effluent from a septic tank.

The above costs which include only the cost of chemicals are expressed in the following table as annual costs, including the labor for each thousand gallons of sewage treated under the different conditions experimented with. It is understood, of course, that the results here discussed and these approximate cost data refer to strictly domestic sewage and it is further to be stated that the feature of depreciation and interest has not been considered, factors which, of course, are of great importance in considering operating costs on a large scale.

TABLE NO. 40.

Cost Per Thousand Gallons Per Annum at Experimental Plants Studied.

Place.	Character of Sewage.	Copper Sulphate.	Chloride of Lime.
St. Mary's of the Springs....	Crude Sewage	$18 55	.....
Westerville	Effluent Contact Filters.	11 77	.....
Boys' Industrial School, Lancaster	Effluent Sand Filters...	6 93	$5 78
Marion	Effluent Sand Filters...	4 86	2 43
Marion	Effluent Contact Filters.	.....	2 73
Marion	Effluent Septic Tanks...	.....	8 83

SUPPLEMENTARY REPORT.

PART II.

STREAM POLLUTION BY ACID IRON WASTES AT SHELBY, OHIO, AND MEANS FOR ITS PREVENTION.

Stream pollution by acid iron wastes has been in evidence at Shelby, Ohio, since the operation of the Shelby Steel Tube Company's plant built in the year 1890 and the pollution of Black Fork, due to the discharge of these wastes has been the cause of a number of law suits on the part of the riparian owners.

The liquid wastes from the tube works result in part from dipping the tubes in a hot dilute solution of sulphuric acid, for the purpose of removing the surface coating of rust. After prolonged use, the acid in this pickling liquor or acid bath becomes neutralized and is no longer effective. An additional volume of waste liquors results from rinsing the tubes after they have been removed from the pickling bath.

In 1903, in connection with a general study of different types of stream pollution, the United States Geological Survey undertook an exhaustive study of a method for purifying the wastes, acting co-operatively with the Ohio State Board of Health. These studies were supplemented during the Board's special investigation of Ohio sewage purification plants. by further inquiries relative to the feasibility of removing the acid and iron from the more dilute rinsing liquors.

To prevent the further pollution of the Black Fork by acid iron wastes, as a result of the co-operative investigation of the United States Geological Survey and the Ohio State Board of Health, there is in operation a plant for the recovery of copperas from the strong pickling liquors; and following the studies made during the Board's special investigation of sewage purification plants there is now in use a plant for the treatment of the dilute rinsing liquors with milk of lime.

A brief resumé of stream pollution by acid iron wastes at Shelby, a description of the enlarged copperas recovery plant, and a description of the rinse liquor neutralizing plant comprise the subject matter of this supplementary report.

THE POLLUTION OF THE BLACK FORK.

For two years after the Shelby Steel Tube Works were placed in operation in the year 1890, all of the spent pickling liquors were discharged without treatment into a small brook adjacent to the works, thence to the Black Fork, a tributary of the Muskingum River. At Shelby, the Black Fork has a watershed of about 40 square miles and a dry weather flow of perhaps one to three cubic feet per second. On account of the discolored condition of this stream, a suit for damages of $2,500 against the Shelby Steel Tube Works was filed in 1902 in the Court of Common Pleas of Richland County, Ohio. The complainant was one Isaac Noecker, a farmer living on bottom land about five miles below the tube works. The case came to trial in June, 1903, and a verdict was re-

turned favorable to the plaintiff on the grounds that the water of the Black Fork was no longer in its normal state and that an injury was done to riparian owners below the tube works, who by common law have a right to receive the waters of the stream reasonably unpolluted by those living above. The case was appealed to the Circuit Court of Richland County, and then to the Supreme Court of Ohio, but the judgment of the lower courts was affirmed in each instance. This successful suit against the Tube Company encouraged further suits, a number of which have since been filed. Shortly after the first suit was entered, permission was secured from the village of Shelby to discharge the entire flow of acid iron wastes into the city sewerage system, and by this means it was supposed that the pollution of Black Fork would be overcome. The effect, however, of the discharge of the liquors into the Shelby sewers merely transferred the pollution of the Black Fork to a point about three miles further down stream.

The entire volume of pickling liquors continued to flow into the Shelby sewers until 1904 when the first steps were taken to alleviate the pollution of the Black Fork by the installation of a plant for the recovery of copperas from the strong pickling liquors. While the strong iron liquors have been treated at this plant, until August, 1906, a considerable volume of more dilute wastes from rinsing operations, and from leakage from the pickling vats has been discharged into the Shelby sewers to the marked detriment of the sewage purification plant, and as already discussed (See pp 474 to 477), the village withdrew permission formerly given to the tube works to dispose of their iron liquors by discharging them into the sewers of the village. The rinsing liquors were then discharged into Red Brook, a small stream adjacent to the plant and thence to Black Fork, and gave rise to renewed agitation on the part of the riparian owners below.

In September, 1907, there was first operated the rinse liquor neutralizing plant and this together with the copperas recovery plant practically eliminates the discharge of iron wastes into the Black Fork by virtue of (1) concentration of strong liquors for copperas recovery, and (2) neutralization and precipitation of all acid iron wastes too dilute to concentrate profitably.

THE RECOVERY OF COPPERAS.

As noted, the recovery of copperas from the spent pickle has been carried out since 1904. The following is a description of the plant and methods of operation.

Description of Plant.

Increasing activities at the tube works have necessitated an enlargement since originally built, and the plant now comprises a storage tank, evaporators, and crystallizing tanks, as follows:

Storage Tank. The hot liquor from the pickling vats flows by gravity into a lead lined storage tank, of rectangular cross-section and of about 6,000 gallons capacity.

Evaporators. From the storage tank the liquor flows by gravity into evaporators. These are three in number and are built of wood. They are rectangular in plan, trapezoidal in elevation, and have a capacity of about 2,000 gallons each. The evaporators are lined with ¼-inch sheet lead and are heated by steam coils. The tanks are provided with wooden hoods and a forced draught for removing acid vapor and steam.

Crystallizing Tanks. The hot liquors concentrated in the evaporators are discharged into iron crystallizing tanks, thirteen in number and nested in wooden tanks. To insure a low temperature in the summer months, and thus a more rapid crystallization and a greater yield of crystals, a stream of water is caused

to circulate in the space between the two tanks. The inner iron tanks are rectangular in plan and of about 660 gallons capacity each. To facilitate crystallization, each tank is provided with a large number of wooden strips hung on hooks and submerged in the liquor about three feet.

Operation.

The stored liquor is admitted into an evaporator, and steel or iron turnings are introduced to neutralize free acid and to reduce all the iron to the ferrous state. The liquor is then concentrated to about 45 degrees Baumé (Sp. Gr. 1.453) and, when sufficiently concentrated is discharged into the crystallizing tanks and allowed to cool and crystallize. Full crystallization takes place in the water cooled tanks in about twelve hours. The crystals are then removed and the mother liquor is pumped back to the raw liquor storage tank or to one of the evaporators. Under usual operating conditions, there are no by-products from this process, and the Black Fork suffers no pollution from this source.

Costs.

For all available information relative to the cost of copperas recovery by this plant, see U. S. Geological Survey Water-Supply and Irrigation Paper No. 186, pp. 34-35.

NEUTRALIZATION AND PRECIPITATION OF RINSING LIQUORS.

The continued pollution of the Black Fork by acid iron wastes encouraged a continuance of suits to recover damages. as before stated, and in these cases from both the tube works and the village of Shelby. In the early part of the special investigation, therefore, the State Board of Health made a thorough examination of existing conditions and, as previously discussed, (See pp. 473 to 477), advised the village of Shelby to withdraw permission given to the tube works in 1902 to discharge their acid iron wastes into the city sewers. This step meant a greater pollution of the Black Fork in the village proper and after studying the problem with some thoroughness, the Board suggested to the tube work's officials a plan for neutralization and precipitation of the acid rinsing liquors by milk of lime.

When the copperas recovery plant was first placed in operation, the volume and strength of the acid rinsing liquors were considerably less than at the present time, and their discharge in a raw state into the Shelby sewers was not considered a detriment to the efficiency of the purification of the sewage of the village. The continued increase in the quantity of steel pickled, however, caused a decided increase in the volume of rinsing liquor which for sometime past has seriously interfered with the normal purification of the Shelby sewage; hence, suggestions for treatment and removal from the village sewers.

Since about September 1, 1907, these liquors have been neutralized by milk of lime by the plant, suggested in outline by the State Board of Health and designed in detail by the engineering department of the Shelby Steel Tube Company, the Ohio State Board of Health acting in a consulting capacity.

Prior to the construction and completion of the rinse liquor neutralization plant, a thorough study was made by the engineering department of the Board as to the character and volume of the several waste liquors. It was found that these wastes comprised acid iron rinse liquors, roughly treated rinsing liquors, and cooling water from the rolling mill. producer gas plant and piercing machines. Of these, practically only the rinsing liquors are important with reference to the pollution of the Black Fork from acid iron wastes, since the remaining liquors, although of larger volume, contain practically no free acid and but little iron.

Composition of Waste Liquors.

During an investigation of July 30, 1906, samples were collected of the discharge of the waste rinsing liquors at the outlet of the rinsing tanks, and also of the so-called treated liquors. (The treatment consisted merely in the discharge of the liquor into a trench containing several barrels of unslaked lime. Generally speaking, practically little improvement in the liquor was thus effected.) Samples were collected from the outlet of the tanks with a view to obtaining a composite sample of the rinse liquor uncontaminated by leakage and splashings from the pickling tanks proper. On this account, the mixed liquors as discharged from the mill probably would show somewhat higher percentages of iron and free acid. The considerable quantity of iron as copperas and the acid character of the dilute rinsing liquors are clearly illustrated by the analyses in Table No. 1

TABLE NO. 1.

Composition of Rinsing Liquors and Other Liquid Wastes from The Tube Works on July 30, 1906.

Source.	Grains Per Gallon.			Grams Per Liter.	
	Iron (Fe.)	Copperas ($FeSO_4 \cdot 7H_2O$)	Sulphuric Acid (SO_4.)	Iron (Fe.)	Sulphuric Acid (SO_4.)
Rinse Liquor	374	1870	142	6.38	2.44
Rinse Liquor	647	3255	268	11.03	4.59
Treated Liquor	544	2720	136	9.31	2.33
Treated Liquor	538	2690	96	9.21	1.65
Treated Liquor	606	3030	135	10.36	2.32
Rolling Mill Waste	26	.....	0	0.45	0.00
Piercing Mill Waste	16	.....	0	0.28	0.00

On August 28, 1906, a further study was made of the waste pickling liquors. For a period of twenty-four hours, samples were collected in equal portions at 15-minute intervals from the discharge of one of the rinsing tanks, and at the end of two hours the individual portions were mixed to form a composite sample. These average samples were examined for iron and free acid by Mr. George M. Goodspeed, in the laboratory of the Steel Tube Company at McKeesport, Pa. From a study of these analytical data, it is evident that the liquors vary greatly in their content of free acid and dissolved iron (ferrous sulphate), and that practically very little iron exists suspended as ferric oxide. The considerable quantity of both free acid and dissolved iron found in these average samples made it clear that pollution of the Black Fork by acid iron wastes would always continue so long as these rinsing liquors were discharged from the works without treatment. The results of the analyses of the samples collected at this examination are shown in the next table.

The quantity of liquors was shown by measurements obtained at this test to be in the vicinity of 25,000 gallons. It was further brought out that there is very little relation between the maximum sewage flow and the maximum

strength of the liquor with respect to acid and iron. For the treatment of these wastes, consequently, a suitable plant must be sufficiently flexible to handle a liquor of varying flow and one which shows wide independent variation in dissolved iron and free acid.

TABLE NO. 2.

*Analyses of Rinsing Liquors Showing Range in Composition for Twenty-four Hours on August 28, 1906.**

	Free Sulphuric Acid (H_2SO_4).		Suspended Iron Fe_2O_3.		Dissolved Iron $FeSO_4$ $7H_2O$.	
	Parts per Million.	Grains per Gallon.	Parts per Million.	Grains per Gallon.	Parts per Million.	Grains per Gallon.
Maximum	3900	228	140	8.2	8800	515
Minimum	2500	146	47	2.8	6300	164
Average	3200	187	72	4.2	2800	369

* Examined in laboratory of tube works at McKeesport, Pa.

Proposed Treatment.

The most practical and presumably the cheapest method of treating the acid rinsing liquors appeared to be neutralization and precipitation with lime. Rough tests carried out at the works on a small scale, indicated a copious precipitate of ferrous hydroxide, subject to rapid subsidence, under the application of sufficient lime to show a slight alkalinity to phenolphthalein. It was proposed, therefore, that a plant be constructed with a nominal capacity of about 30,000 gallons daily for treating the waste rinsing liquors with milk of lime. Subsequently a conference was held in Columbus between officials of the tube works and of the Board, and the design of the plant was tentatively adopted.

Description of Plant.

As constructed, the leading features of the plant comprise two neutralizing tanks, a lime slacking tank, a lime storage bin and facilities for sludge disposal and for the removal of the supernatant liquor.

Lime Tank and Lime Storage House. All the rinsing liquors from the plant are discharged into a 10-inch vitrified pipe sewer which leads to the neutralizing plant. On this sewer, near the lime storage shed, there is a concrete manhole 2 feet 6 inches square in plan and 18 inches deep, and as originally arranged, the milk of lime is discharged from the lime tank at this point. A wooden frame building, 24 x 40 feet in plan, contains provision for storing lime in bulk and a tank for preparing milk of lime. The lime slaking tank is a cypress tank, 6 x 12 feet in plan and 4 feet deep, and of about 2,000 gallons capacity. A grid of 1½-inch wrought iron pipe originally provided in the bottom and arranged for agitation with air, was subsequently removed since it clogged rapidly and was very inefficient. The milk of lime flows from the tank by gravity through a 4-inch outlet controlled by a wooden plug on to a concrete floor which slopes to a sump, which leads into the rinse liquor sewer through an 8-inch vitrified pipe. As constructed first, the mixed lime and acid liquors pass through the same 10-inch sewer to the neutralizing tanks.

Neutralizing Tanks. The neutralization of the acid liquors is carried out in cypress tanks, two in number, 25 feet in diameter, 5 feet 6 inches deep and of a capacity of about 15,000 gallons or 2,800 gallons per foot. They are constructed of 3-inch cypress and have a flat bottom, in the center of which is a 7-inch outlet controlled by a wooden plug. The bottom of each tank is covered with a manifold of 1½-inch acid proof pipe which contain ⅛-inch perforations 3 inches on centers staggered. These headers serve for the admission of air for agitation. For the removal of the supernatant liquor after neutralization and precipitation, there is provided a 4-inch cast iron siphon operated by steam through a 1½-inch pipe. The discharge of supernatant liquor takes place through an 8-inch vitrified sewer pipe which leads to the creek. The tanks are supported on wooden blocks which rest on a sloping concrete floor, in the center of which is an 8-inch drain which leads to a pond for the reception of the sludge.

Method of Operation.

The plant was first placed in service on August 21, 1907 and since that time practically no unneutralized rinsing liquor has been discharged from the tube works. The method of operation was at first substantially as follows:

Raw rinsing liquor is allowed to discharge into one of the tanks until the tank is about two-thirds full. Milk of lime previously slacked, and at a concentration of roughly 15 per cent. is admitted into the stream of crude rinsing liquors, thence to the neutralizing tank, until under agitation with air there is obtained an alkaline reaction to phenolphthalein. As the tank fills with raw liquor, more lime is added under continued air agitation until finally the tank is filled to within about 6 inches of the top, corresponding to about 13,000 gallons of liquor, and contains a neutralized and precipitated iron waste which shows a slight pink color with phenolphthalein. When one tank is thus filled, the raw waste is discharged into the second tank. A neutralized tank of liquor is allowed to stand for from 8 to 12 hours, and then the clear supernatant liquor is removed by the siphon. The sludge is then rinsed with a stream of water from a hose through an opening in the bottom on to the sloping concrete floor beneath, thence to the sludge pond.

From August 23 to September 12, 1907, the plant was operated substantially as above described and 29 tanks of rinse liquors were neutralized. The total lime used was 37.4 tons and the total volume of liquor treated was 392,000 gallons, or roughly 14,000 gallons per day. The lime applied was at the rate of 104.8 tons per million gallons. The supernatant liquor removed averaged 40 per cent of the total volume of liquor neutralized and the sludge produced totaled 1,200 cubic yards, or 3,270 cubic yards per million gallons.

The tremendous quantity of sludge formed and the large quantity of lime required suggested that immediate steps be taken to reduce the quantity of liquor produced. This was attempted by cutting down the quantity of rinse water and eliminating all leakage from the pickling vats. but resulted in the production of a rinsing loquor so strong that the practice could not be continued and it was, therefore, necessary to return to former methods of rinsing. Continued operation of the plant, produced so much sludge that the sludge pond proved inadequate, especially as so much water was necessary to flush the heavy sludge from the tanks. It was then suggested to prepare excavations on cinder filled land adjacent to the plant to which the sludge was to be pumped. For this purpose there was purchased an Emerson pump with a 3-inch suction, a 2½-inch discharge and a capacity of 225 gallons per minute. The lift is 10 feet and the sludge is pumped through about 200 feet of 2½-inch wrought iron pipe. Since so much water is necessary to dilute the sludge, it was then decided to pump the entire contents

of the neutralizing tank immediately after neutralization is complete, and it is understood that this has been the practice since that time. The piping between the two precipitation tanks was so arranged that the liquid could be pumped from either one or both. The mixture of green ferrous hydrate and water is now pumped on to a large excavation in this porous cinder fill and the water seeps away leaving the sludge which eventually oxidizes and is materially reduced in volume. It is of interest to note that violent agitation with air for several hours failed to show an appreciable oxidation of the ferrous hydroxide in the precipitation tank even though there was a large excess of lime present.

Prior to making this change, it was found necessary to repipe the lime solution as it was not found practicable to allow the raw liquor and the milk of lime to flow in the same sewer owing to stoppages. Accordingly, there was constructed a separate 10-inch sewer for the lime with a fall of 25 inches in 150 feet, so that the lime is not applied to the raw liquor until it reaches the neutralizing plant. Since this time the plant has been operated without stoppages and it is said that there has been no further difficulty with respect to sludge disposal.

PRESENT STATUS AND EFFICIENCY OF RINSE LIQUOR TREATMENT.

On October 14, 1907, the tube works were visited after the rinse liquor plant was in full operation and in addition to samples of the treated liquor there was collected a series of samples of the waters of the small brook adjacent to the plant at points above and below the works, and also of the Black Fork at several points in the village of Shelby and below. The samples covered the Black Fork from the confluence with Red Brook to a point 150 feet below the outlet of the Shelby sewage plant. These samples were collected particularly to learn the presence or absence of free mineral acid, the actual quantity of iron which was then reaching the Black Fork and the extent to which the effect of the iron introduced near the tube works could be detected in the waters of the stream.

The results of this survey are shown in a table below. A study of these results shows first that no free mineral acid was then being admitted into the Black Fork, although there was a decided acidity on the part of the samples collected near the plant due no doubt to the presence of iron salts, chiefly copperas. It is especially to be noted that while a small quantity of iron waste or iron in some form was still reaching the Black Fork through the medium of Red Brook — due no doubt to leachings from the soil which is saturated with iron — yet after flowing about one-half a mile, the iron is precipitated so that there is practically but slight discoloration of the water beyond this point. All samples collected below the C. C. & St. L. R. R. bridge at Shelby Junction indicate a normal surface water with but small quantities of iron.

TABLE NO. 3.

Results of Chemical Analyses of Samples of Water from Red Brook Above and Below the Tube Works and from the Black Fork in the Village of Shelby and at Several Points Below.

Sampling Points.	Parts Per Million.				
	Iron (Fe).			Alkalinity.	
	Total.	Dissolved.	Suspended.	Methyl Orange.	Acidity* Phenolphthalein.
Red Brook —					
500 ft. above tube works	0.3	0.2	0.1	217	22
100 ft. below first drain from works	25.0	0.6	24.4	98	200
100 ft. below neutralizing plant	40.0	15.0	25.0	47	224
At Walnut Street bridge	30.0	4.0	26.0	45	146
At confluence with Black Fork	30.0	7.5	22.5	30	130
Black Fork —					
200 ft. below Main Street, Shelby	25.0	0.5	24.5	62	96
100 ft. below C. C. & St. L. R. R. bridge near Shelby Junction	2.4	0.3	2.1	94	48
At Dempsey's bridge, 1 mile below Main Street, Shelby	0.4	0.3	0.1	97	22
150 ft. below outlet Shelby sewage plant	1.7	0.4	1.3	126	21
Effluent from Shelby sewage plant	1.9	0.3	1.6	275	41

* Expressed in terms of calcium carbonate ($CaCO_3$).

In addition to these samples, there were collected for analysis samples of the raw and treated liquors from the neutralizing plant. The raw liquor at this time was unusually strong because of the restricted use of rinse water, and contained 5.55 per cent of copperas ($FeSO_4\ 7H_2O$); the free acid was 0.25 per cent. As before stated, such restricted use of rinse water was very soon discontinued and the present composition of the waste probably is similar to that indicated by the analyses already presented. The neutralized liquor when allowed to settle was alkaline and contained 216 parts per million of calcium oxide, (CaO) and practically no iron (0.1 part per million). It is to be recalled that this liquor which contains suspended ferrous hydrate is now being pumped to a sludge area, which retains the suspended matter so that the liquid portions of the neutralized liquors, alone eventually reach the Black Fork and it is evident that pollution by iron and acid from the rinsing liquors has now been entirely prevented.

SUMMARY.

To prevent a continuance of the polluted condition of the Black Fork, there are in operation at the Shelby tube works two plants, one of which provides for the recovery of copperas from the spent pickling liquors and the other effects a neutralization of free acid and a precipitation of the iron contained in the rinsing liquors which are too dilute to concentrate profitably. The other wastes which result from the water used for cooling purposes contain no free acid and but

slight quantities of iron and cannot be said to be of moment with respect to the pollution of the Black Fork by acid iron wastes. The recent survey of the waters of the Black Fork in the village and at several points below indicate that the acid iron waste pollution has now been overcome. Furthermore, evidence obtained during this investigation has shown that conditions in regard to iron and free acid at the Shelby sewage purification plant have decidedly improved and that there will probably be no further cause for complaints, due to the discharge of the effluent from the treatment of the Shelby sewage. Although there was some iron reaching the Black Fork, on the examination made in October, 1907, yet it appears that this pollution will gradually cease, as the saturated land adjacent to the tube works looses its iron. It appears, therefore, to be clear that there are no further grounds for complaint on the part of riparian owners, due to the pollution of the Black Fork by spent liquors from the steel tube company's works.

COSTS.

The plans for the acid rinsing liquor neutralizing plant were prepared by the engineers of the tube works and the plant was constructed by the labor force of the company. From information obtained from the superintendent of the tube works it appears that the actual cost of the plant was about $4,700. Of this amount, about $1,000 is stated to be in excess of what would be considered an average cost figure owing to the fact that the plant was built upon filled land and there was thus necessitated unusually expensive foundations.

From available information, the operating expenses can only be roughly estimated as follows: Based upon the treatment from August 23 to September 12, 1907, the average quantity of liquor is about 14,000 gallons daily, and requires 1.33 tons of lime, or a cost of $6.65 per day with lime at $5.00 per ton. To this cost is to be added the labor item of one attendant who directs the application of lime and the subsequent pumping of the neutralized waste. In addition to this, there is a small cost for steam and occasional labor items. An estimate of the daily operating expenses is in the vicinity of $9.00. The cost of chemical per million gallons reaches the high figure of $524.00 and it is to be noted that the waste is exceptionally strong both in copperas and free acid so that for neutralization with lime, there are required quantities of this chemical far in excess of those incidental to the use of coagulants in water purification or for precipitants in the treatment of domestic sewage.

LIST OF PLATES.

WATER PURIFICATION PLANTS.

I — Batavia — Water and Light Plant.
II — Bucyrus — Details of Filter.
III — Cincinnati — Sketch Showing General Arrangement of Water Purification Plant.
IV — Cincinnati — Details of Filter.
V — Dennison — Details of Filter.
VI — Elyria — Sketch Showing General Arrangement of Water Works.
VII — Fostoria — General Plan of Water Works.
VIII — Gallipolis — Details of Intake.
IX — Geneva — General Details of Water Works.
X — Geneva — Details of Filter.
XI — Lorain — Details of Old Filter.
XII — Lorain — General Details of New Filter Plant.
XIII — Lorain — Details of New Filter.
XIV — Marietta — Sectional Plan of Filter House.
XV — Marietta — Details of Filter.
XVI — Newark — Sketch Showing General Arrangement of Water Works.
XVII — Rocky River — Plan and Section of Filter Plant.
XVIII — Vermillion — Details of Water Works.
XIX — Warren — Details of Filter.
XX — Youngstown — General Plan of Water Works.
XXI — Youngstown — Sectional Plan of Filter House.
XXII — Youngstown — Details of Filter.
XXIII — Oberlin — Elevation and Plan of Pressure Filters.

SEWAGE PURIFICATION PLANTS.

XXIV — Clyde — General Plan and Sections.
XXV — Ashland — General Plan and Sections.
XXVI — Ashland — Detail Plan and Sections of Septic Tanks.
XXVII — Geneva — Plan and Sections of Septic Tank and Storage Reservoir.
XXVIII — Geneva — Plan and Sections of Sand Filters and Dosing Apparatus.
XXIX — Shelby — General Plan and Details of Sludge Pits.
XXX — Lakewood — General Plan.
XXXI — Mansfield — Sectional Plan and Sections of Septic Tanks.
XXXII — Mansfield — Half Elevation and Sections of Septic Tanks.
XXXIII — Mansfield — Septic Tanks, Details of Inlets and Outlets.
XXXIV — Marion — Plan, Longitudinal Section and Details.

XXXV — Marion — Sectional Plan and Sections.
XXXVI — East Cleveland — General Plan.
XXXVII — East Cleveland — Detail Plan.
XXXVIII — Kenton — Plan and Sections of Septic Tanks, Dosing and Wave Filters.
XXXIX — Alliance, Fairmount Children's Home — General Plan and Sections.
XL — Gallipolis State Hospital — General Plan and Sections.
XLI — Lancaster, Boys' Industrial School — General Plan and Sections of Screen Chamber.
XLII — Lancaster, Boys' Industrial School — Plan and Sections of Filter No. 15.
XLIII — Mansfield State Reformatory — General Plan and Sections.
XLIV — Massillon State Hospital — General Plan and Sections.
XLV — Sandusky, Soldiers' and Sailors' Home — General Plan and Sections.
XLVI — Warren, Trumbull County Infirmary — General Plan and Sections of Septic Tank, Reservoir and Filters.
XLVII — Collinwood, Lake Shore and Michigan Southern Railroad Shops — General Plan and Sections.

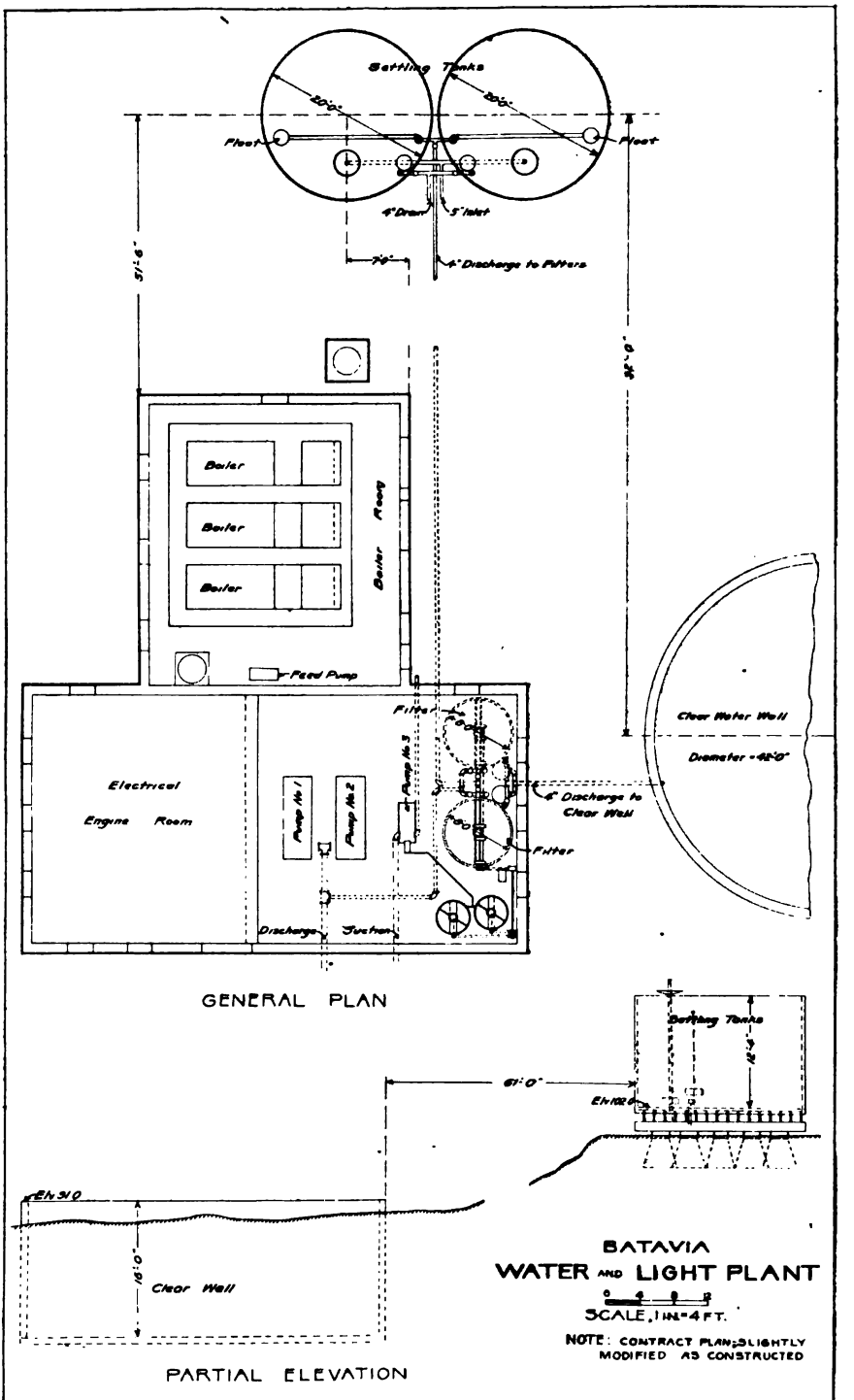

Settling Tanks
Float
Float
4" Drain
5" Inlet
4" Discharge to Filters
Boiler
Boiler
Boiler
Boiler Room
Feed Pump
Electrical
Engine Room
Pump No 1
Pump No 2
Pump No 3
Filter
Filter
4" Discharge to Clear Well
Clear Water Well
Diameter = 42'-0"
Discharge
Suction
GENERAL PLAN
Settling Tanks
61'-0"
El 102
El 91.0
Clear Well
PARTIAL ELEVATION
BATAVIA
WATER AND LIGHT PLANT
SCALE, 1 IN. = 4 FT.
NOTE: CONTRACT PLAN; SLIGHTLY MODIFIED AS CONSTRUCTED

PLATE I.

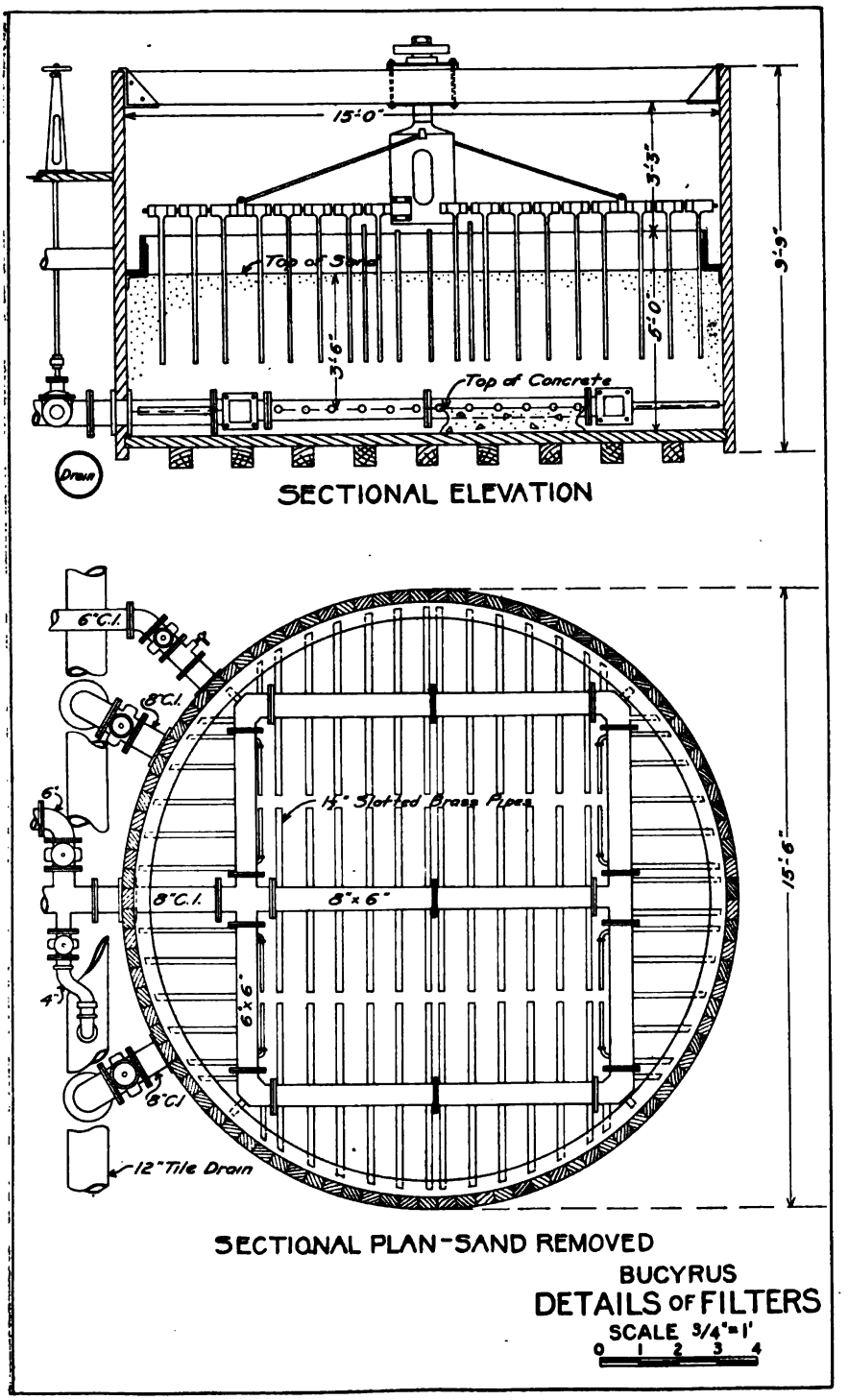

15'-0"
3'-3"
3'-9"
Top of Stone
3'-6"
5'-0"
Top of Concrete
Drain
SECTIONAL ELEVATION
6"C.I.
8"C.I.
6"
1½" Slotted Brass Pipes
8"C.I.
8"x 6"
15'-6"
6"x 6"
4"
8"C.I.
12" Tile Drain
SECTIONAL PLAN-SAND REMOVED
BUCYRUS
DETAILS OF FILTERS
SCALE 3/4"=1'
0 1 2 3 4

PLATE II.

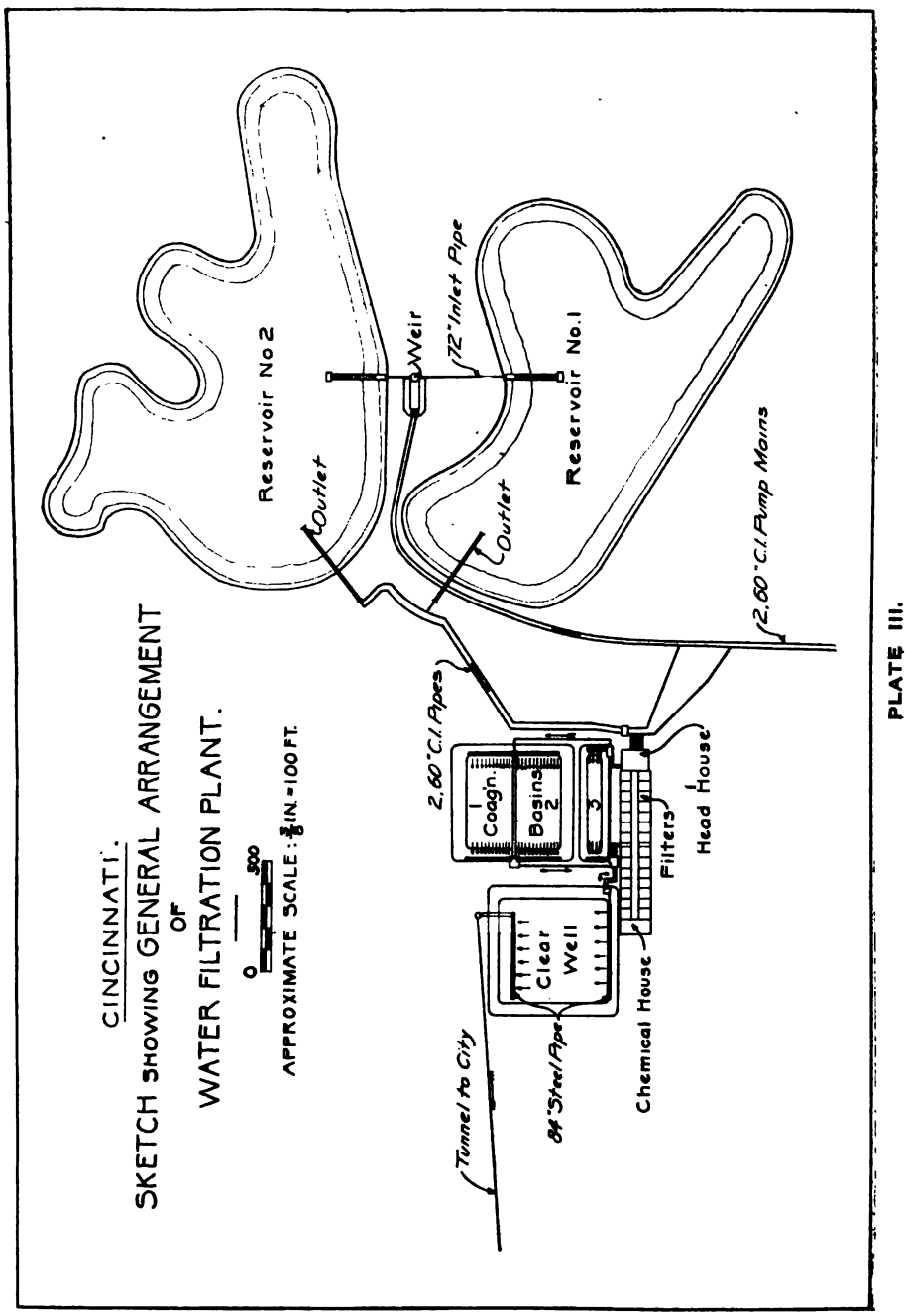

CINCINNATI.
SKETCH SHOWING GENERAL ARRANGEMENT
OF
WATER FILTRATION PLANT.
0 500
APPROXIMATE SCALE: 1 IN. = 100 FT.
Reservoir No 2
Outlet
Weir
12" Inlet Pipe
Outlet
Reservoir No. 1
2,60 "C.I. Pump Mains
2,60 "C.I. Pipes
1 Coagn. Basins 2
3
Clear Well
Filters
Head House
Chemical House
84" Steel Pipe
Tunnel to City

PLATE III.

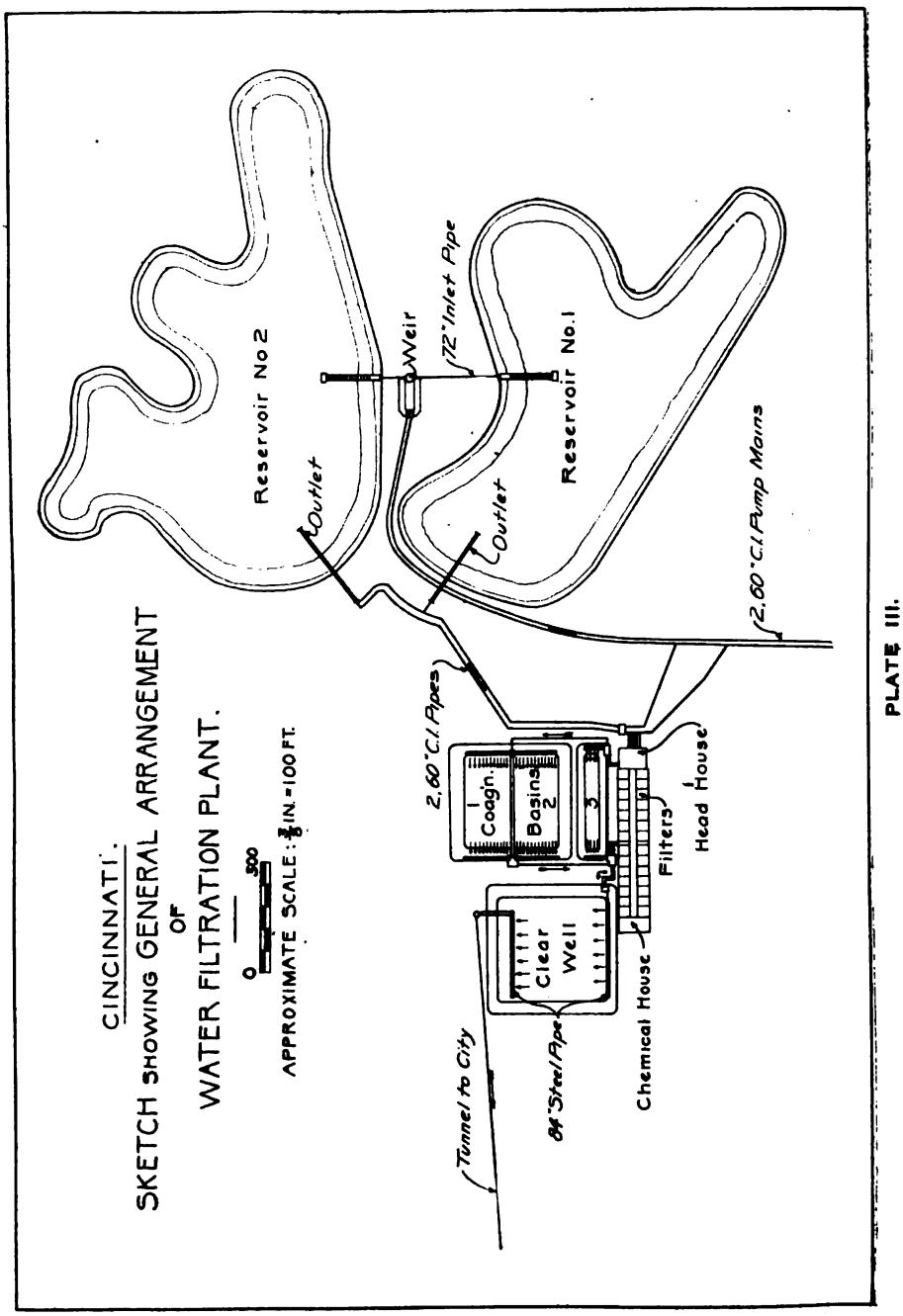

CINCINNATI.
SKETCH SHOWING GENERAL ARRANGEMENT
OF
WATER FILTRATION PLANT.
0 500
APPROXIMATE SCALE: 1/8 IN. = 100 FT.
Reservoir No 2
Outlet
Weir
72" Inlet Pipe
Outlet
Reservoir No. 1
2.60 "C.I. Pump Mains
2.60 "C.I. Pipes
Coagn. Basins
1
2
3
Head House
Filters
Chemical House
Clear Well
84" Steel Pipe
Tunnel to City

PLATE III.

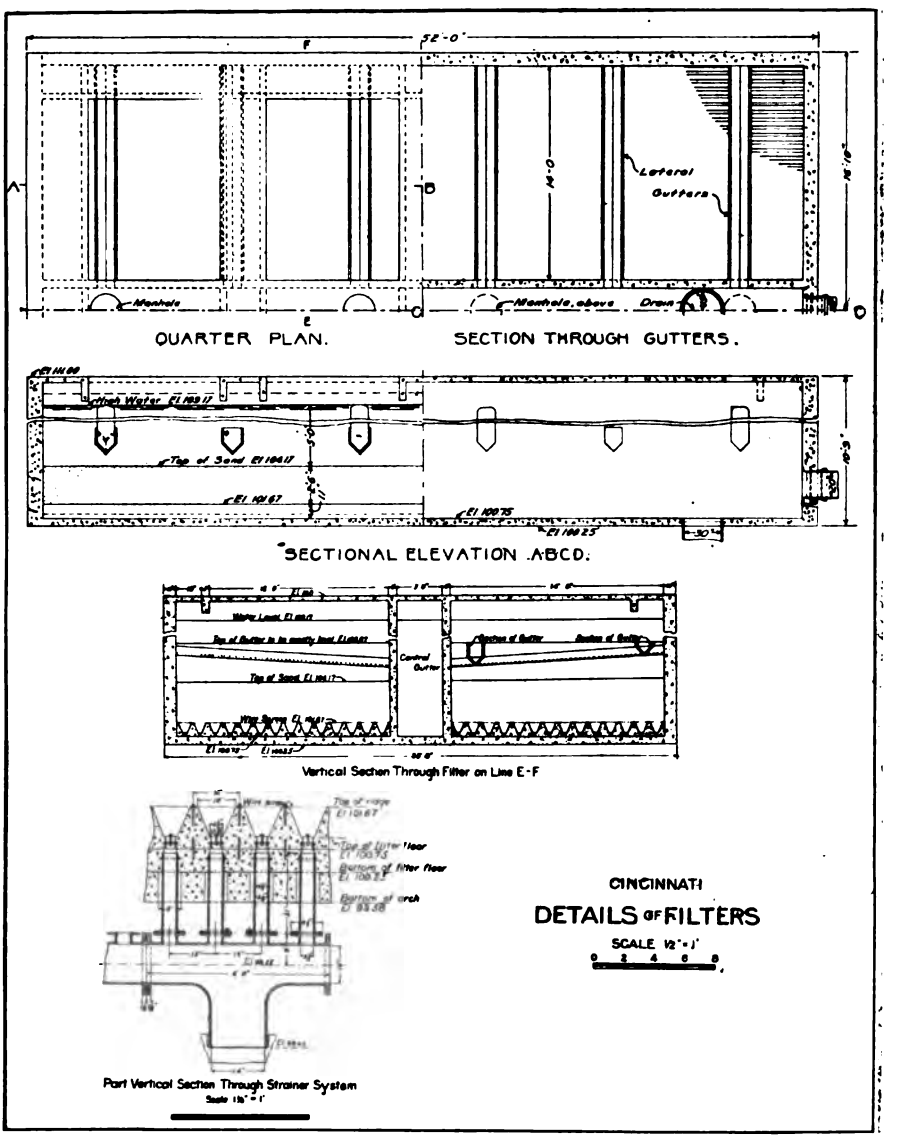

52'-0"
Lateral Gutters
Manhole
Manhole above
Drain
QUARTER PLAN.
SECTION THROUGH GUTTERS.
Wash Water El 109.17
Top of Sand El 104.17
El 101.67
El 100.75
El 100.25
SECTIONAL ELEVATION ABCD.
Central Gutter
Vertical Section Through Filter on Line E-F
Part Vertical Section Through Strainer System
CINCINNATI
DETAILS OF FILTERS
SCALE 1/2" = 1'
0 2 4 6 8

PLATE IV.

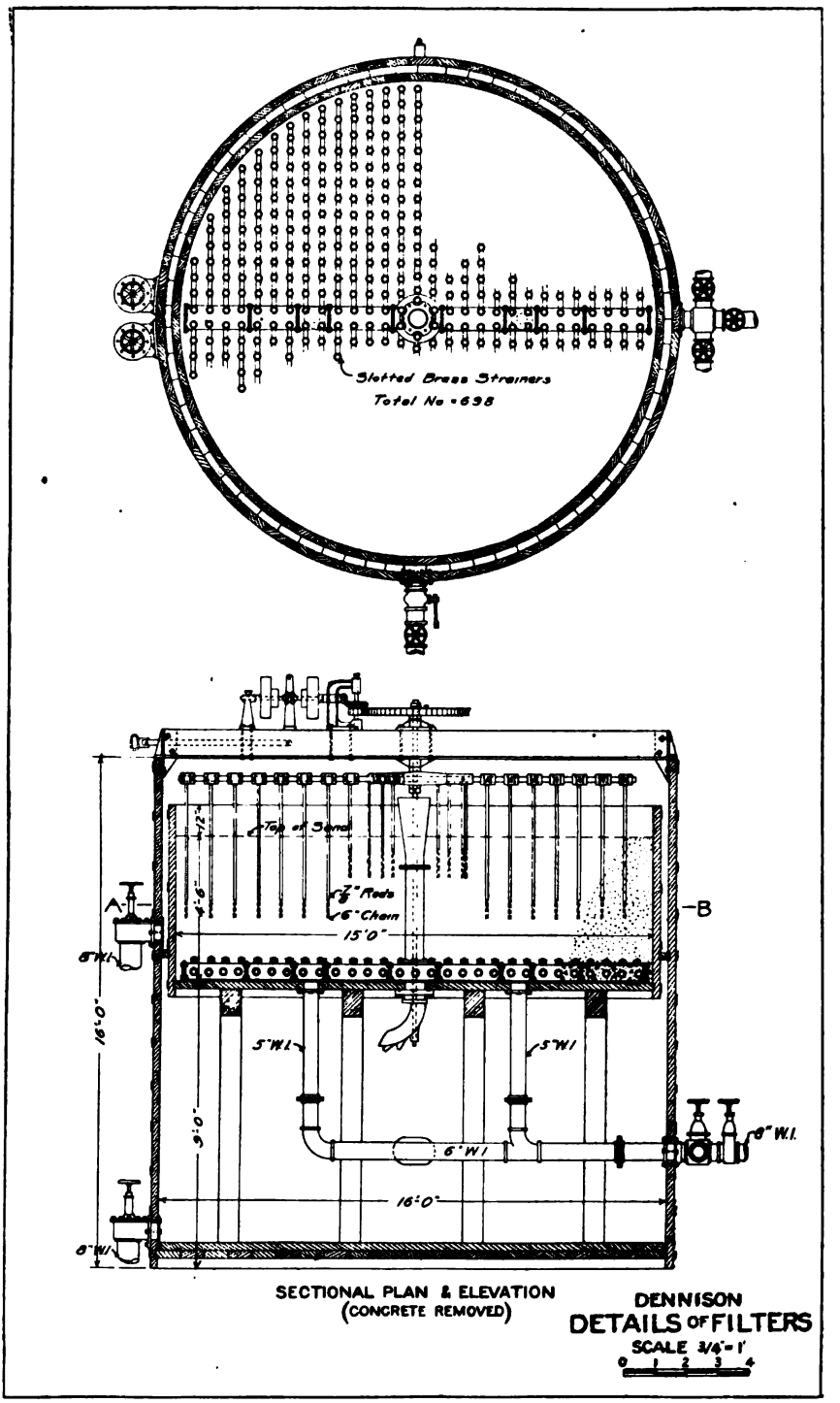

Slotted Brass Strainers
Total No = 698
Top of Sand
12"
4'-6"
7/8" Rods
6" Chain
15'0"
B
6"W.I.
16'0"
5"W.I.
5"W.I.
3'0"
6"W.I.
8"W.I.
16'0"
6"W.I.
SECTIONAL PLAN & ELEVATION
(CONCRETE REMOVED)
DENNISON
DETAILS OF FILTERS
SCALE 3/8"=1'
0 1 2 3 4

PLATE V.

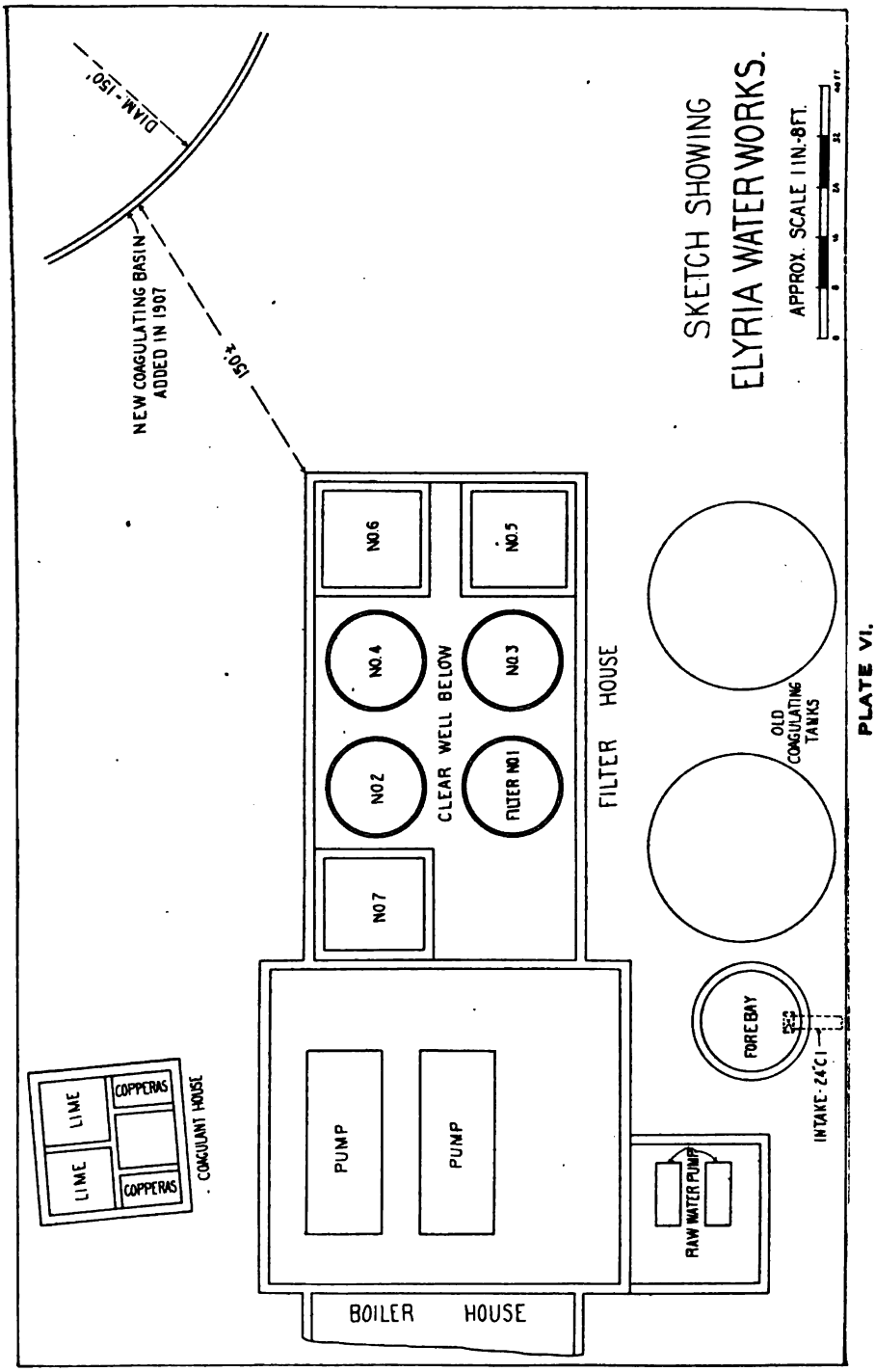

SKETCH SHOWING
ELYRIA WATER WORKS.
APPROX. SCALE 1 IN. = 8 FT.
DIAM. - 150'
NEW COAGULATING BASIN ADDED IN 1907
150'±
NO. 6
NO. 5
NO. 4
NO. 3
NO. 2
FILTER NO. 1
NO. 7
CLEAR WELL BELOW
FILTER HOUSE
OLD COAGULATING TANKS
FOREBAY
INTAKE - 24" C.I.
PUMP
PUMP
RAW WATER PUMP
BOILER HOUSE
LIME
LIME
COPPERAS
COPPERAS
COAGULANT HOUSE

PLATE VI.

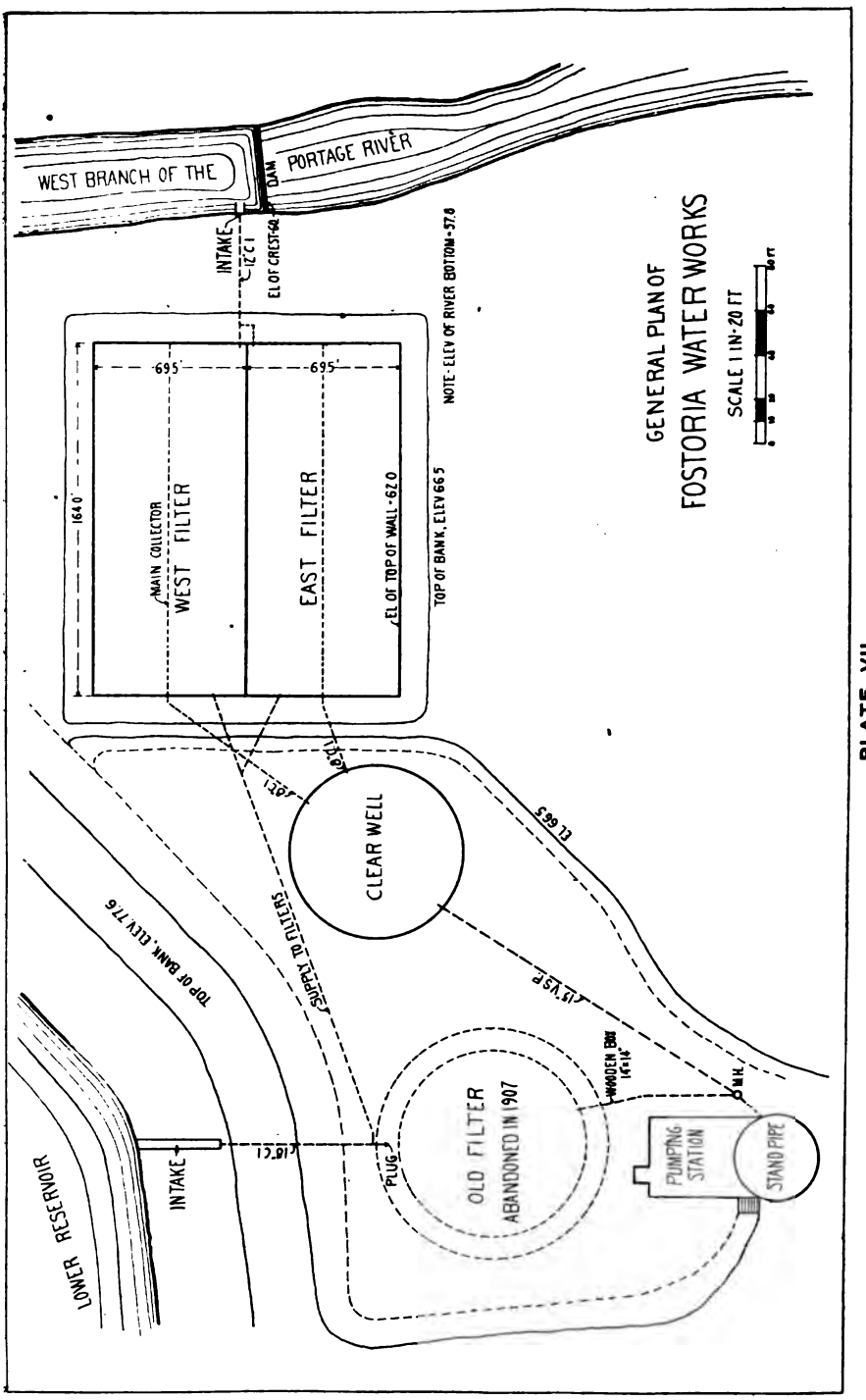

WEST BRANCH OF THE
PORTAGE RIVER
DAM
INTAKE
EL OF CREST-58
NOTE- ELEV OF RIVER BOTTOM-57.0
GENERAL PLAN OF
FOSTORIA WATER WORKS
SCALE 1 IN-20 FT
695'
695'
1640'
MAIN COLLECTOR
WEST FILTER
EAST FILTER
EL OF TOP OF WALL-62.0
TOP OF BANK, ELEV 66.5
CLEAR WELL
SUPPLY TO FILTERS
TOP OF BANK, ELEV 77.6
LOWER RESERVOIR
INTAKE
PLUG
OLD FILTER
ABANDONED IN 1907
WOODEN BOX
PUMPING STATION
STAND PIPE

PLATE VII.

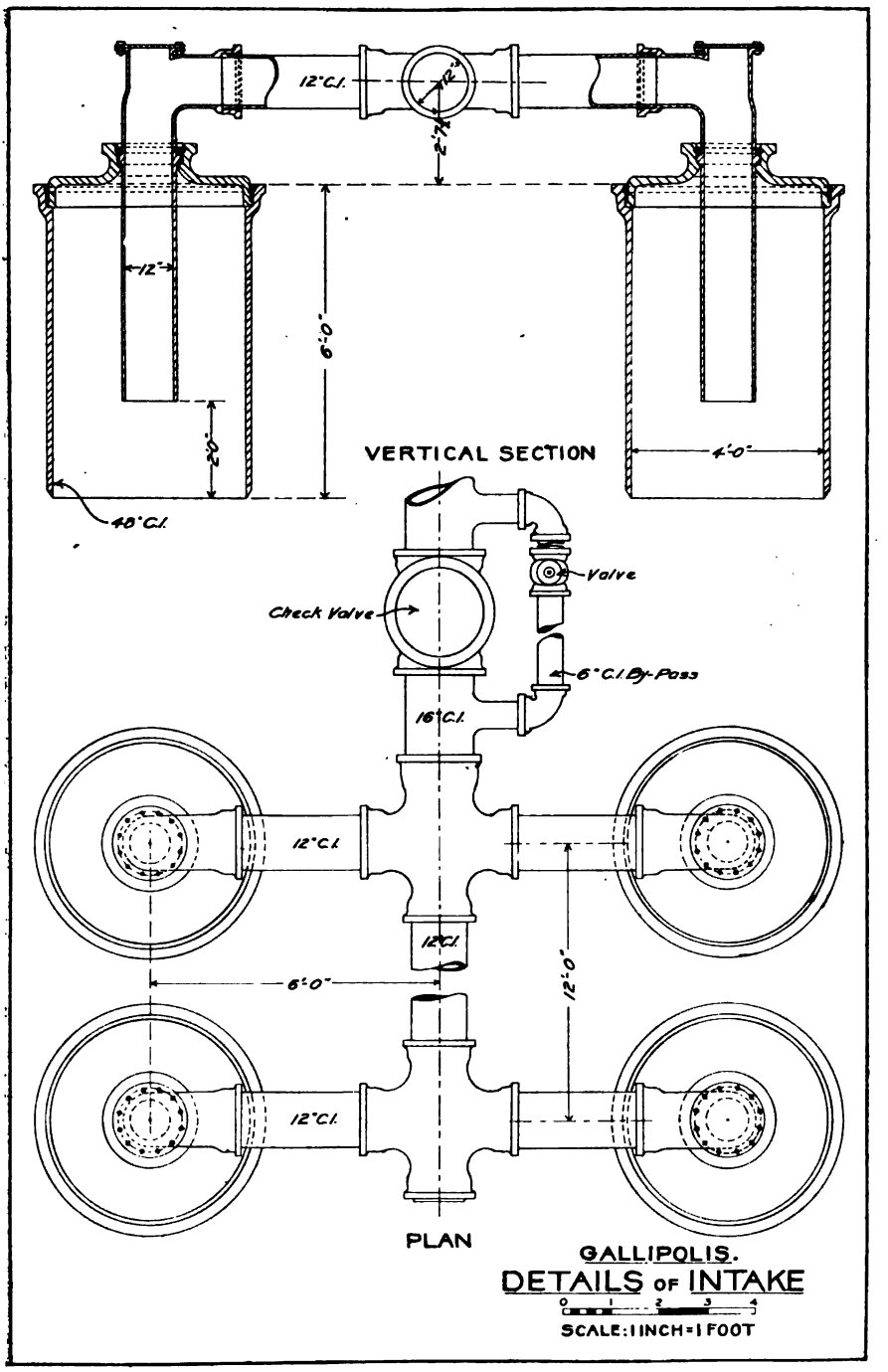
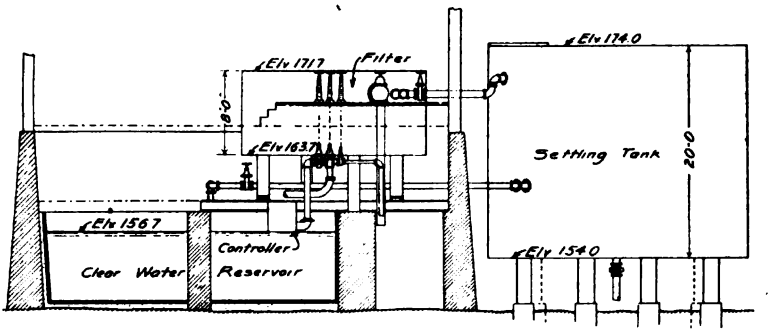
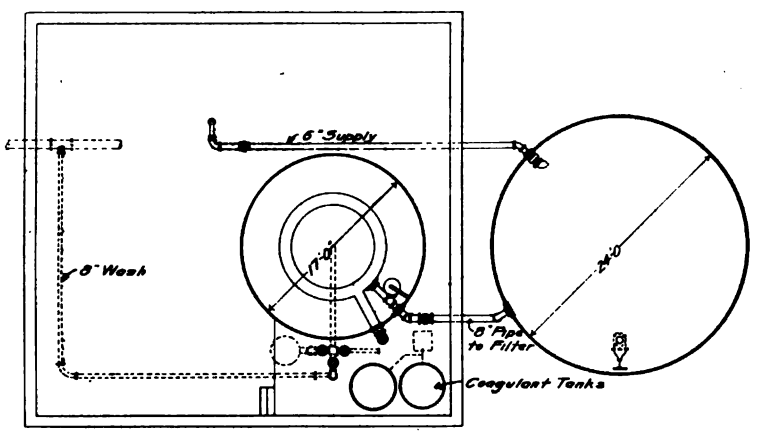

12"C.I.
12"
2'-7"
12"
6'-0"
2'-0"
VERTICAL SECTION
4'-0"
45°C.I.
Valve
Check Valve
6"C.I. By-Pass
16"C.I.
12"C.I.
12"C.I.
6'-0"
12'-0"
12"C.I.
PLAN
GALLIPOLIS.
DETAILS OF INTAKE
0 1 2 3 4
SCALE: 1 INCH = 1 FOOT

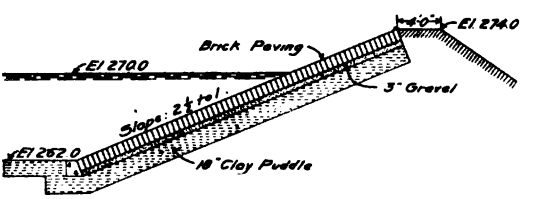
PLATE VIII.



SECTIONAL ELEVATION
OF
FILTER HOUSE



PLAN



SECTION OF RESERVOIR EMBANKMENT.

GENEVA

DETAILS OF WATER WORKS

0 4 8

SCALE 1 IN = 4 FT

PLATE IX.

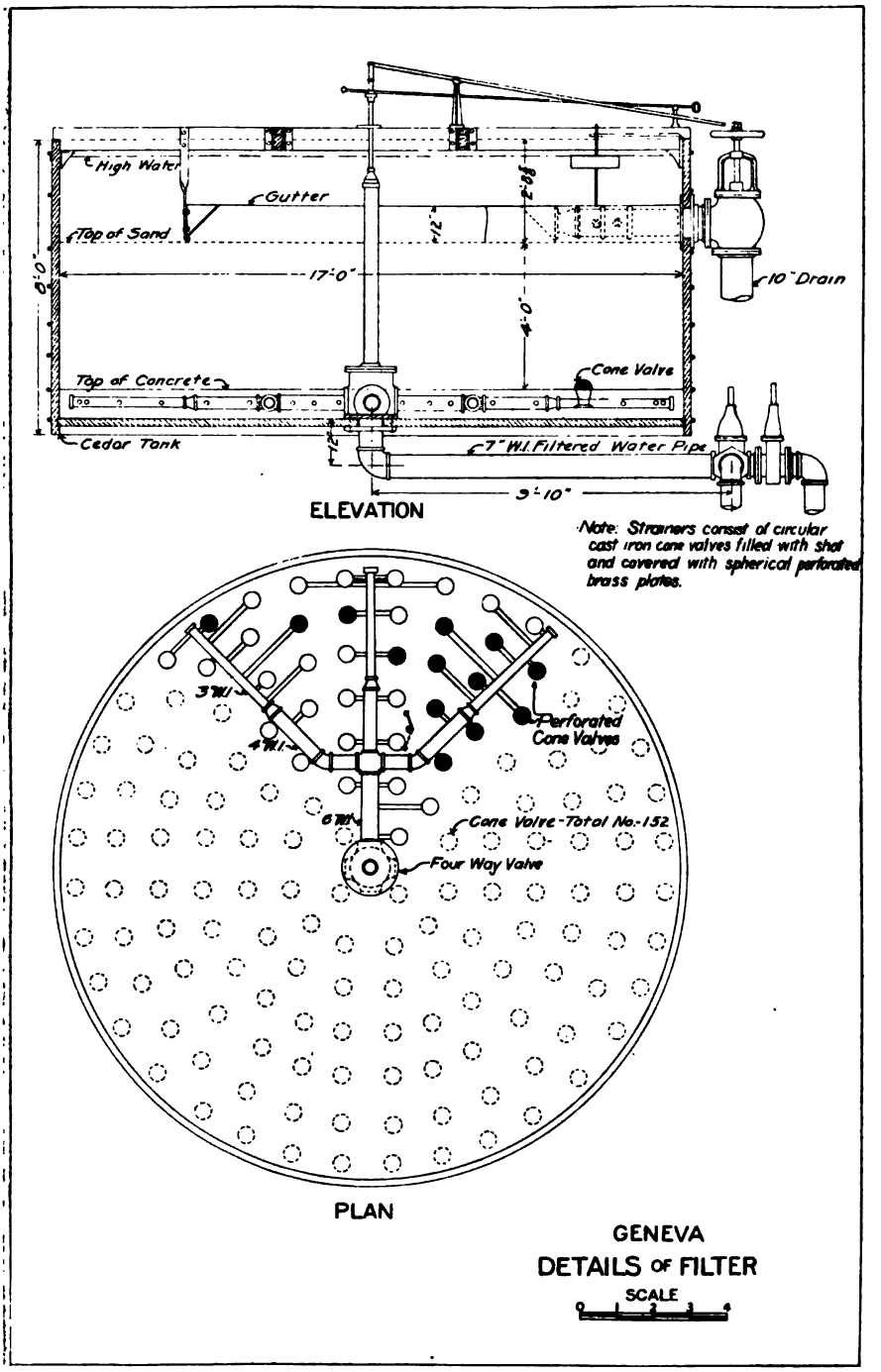
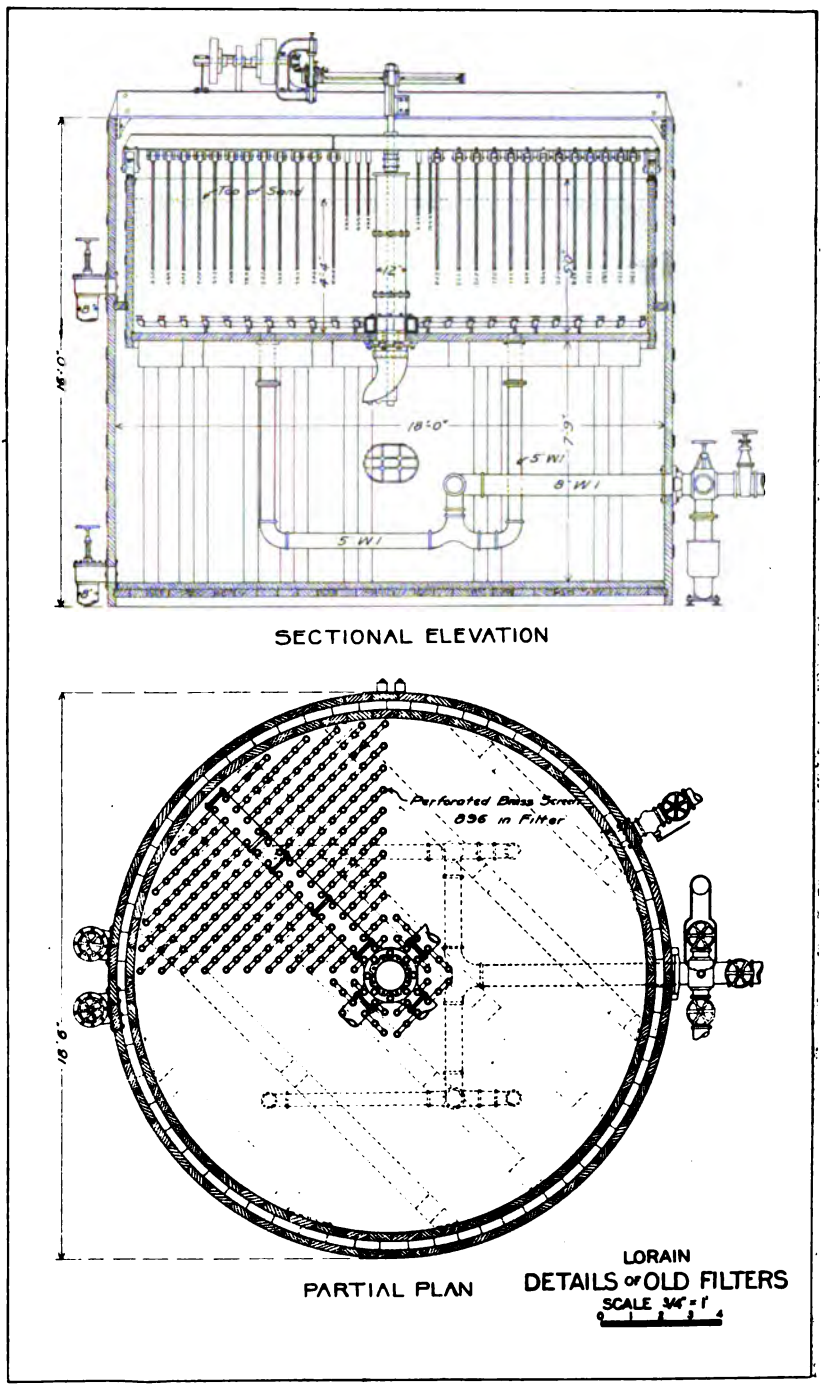

High Water
Gutter
Top of Sand
6'-0"
17'-0"
2'-8"
12"
4'-0"
10" Drain
Top of Concrete
Cone Valve
Cedar Tank
12"
7" W.I. Filtered Water Pipe
3'-10"
ELEVATION
Note: Strainers consist of circular cast iron cone valves filled with shot and covered with spherical perforated brass plates.
3" W.I.
4" W.I.
6" W.I.
Perforated Cone Valves
Cone Valve-Total No.-152
Four Way Valve
PLAN
GENEVA
DETAILS OF FILTER
SCALE
0 1 2 3 4

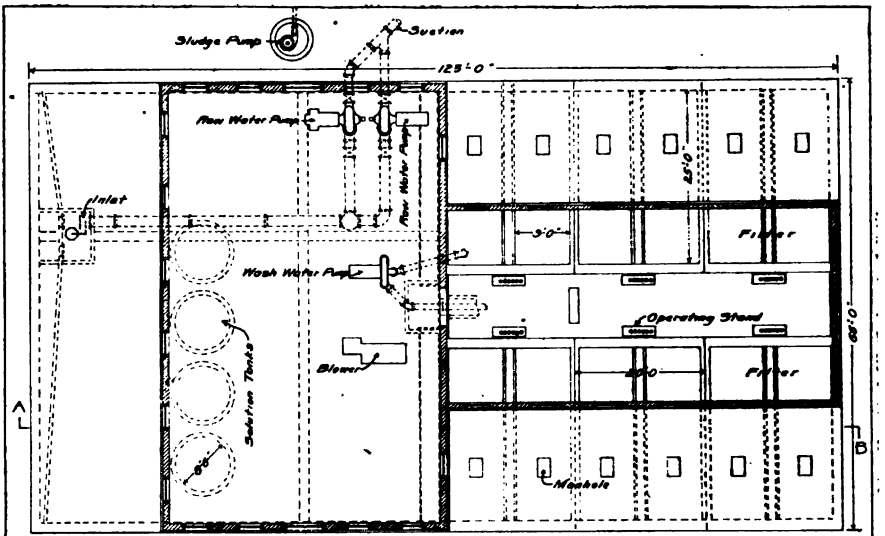
PLATE X.



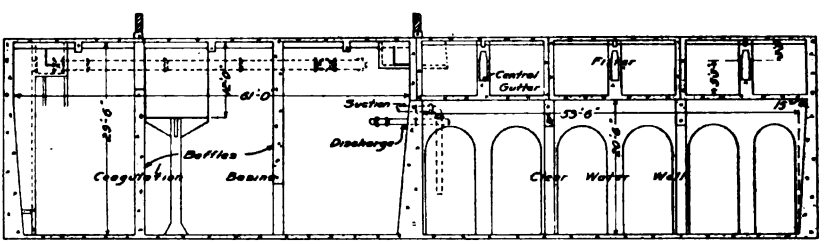
SECTIONAL ELEVATION

PARTIAL PLAN

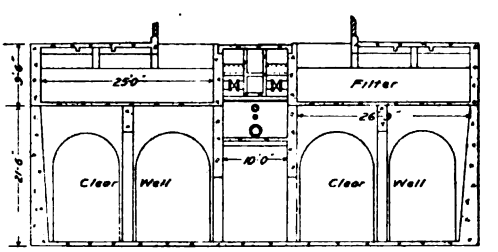
PLATE XI.



SECTIONAL PLAN



SECTIONAL ELEVATION A-B



SECTIONAL ELEVATION

LORAIN
GENERAL ARRANGEMENT
OF
FILTER PLANT
0 5 10 15 20
SCALE $\frac{1}{8}$ IN = 1 FT.

PLATE XII.

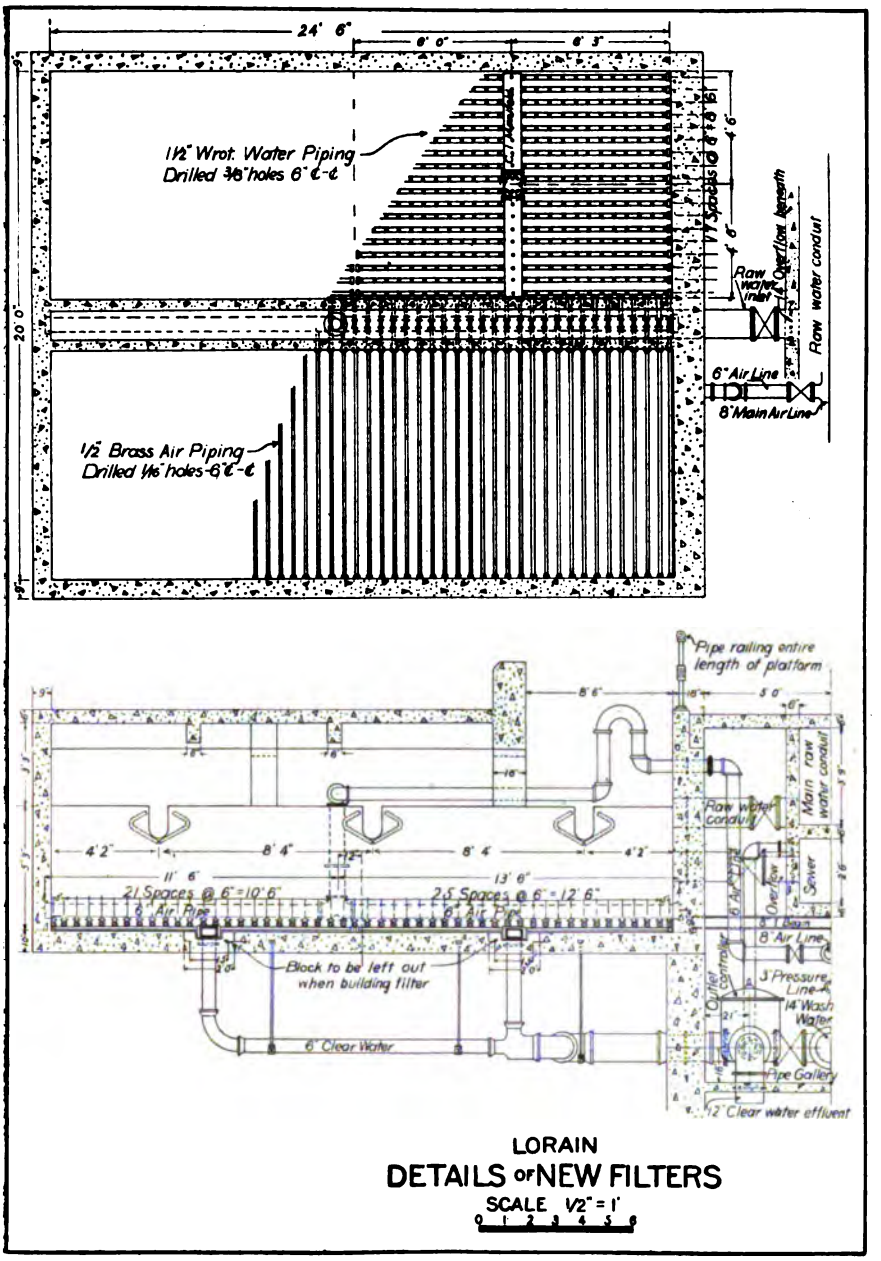

24' 6"
8' 0"
8' 3"
1½" Wrot. Water Piping
Drilled 3/16" holes 6" c-c
1½" Brass Air Piping
Drilled 1/16" holes 6" c-c
20' 0"
18 Spaces @ 6" = 9'
6'
Raw water inlet
14" Overflow beyond
Raw water conduit
6" Air Line
8" Main Air Line
Pipe railing entire length of platform
8' 6"
5' 0"
Main raw water conduit
Raw water conduit
4' 2"
8' 4"
8' 4"
4' 2"
11' 6"
13' 6"
21 Spaces @ 6" = 10' 6"
6" Air Pipe
25 Spaces @ 6" = 12' 6"
6" Air Pipe
Sewer
Block to be left out when building filter
8" Air Line
Outlet controller
3" Pressure Line
14" Wash Water
6" Clear Water
Pipe Gallery
12" Clear water effluent
LORAIN
DETAILS OF NEW FILTERS
SCALE 1/2" = 1'
0 1 2 3 4 5 6

PLATE XIII.

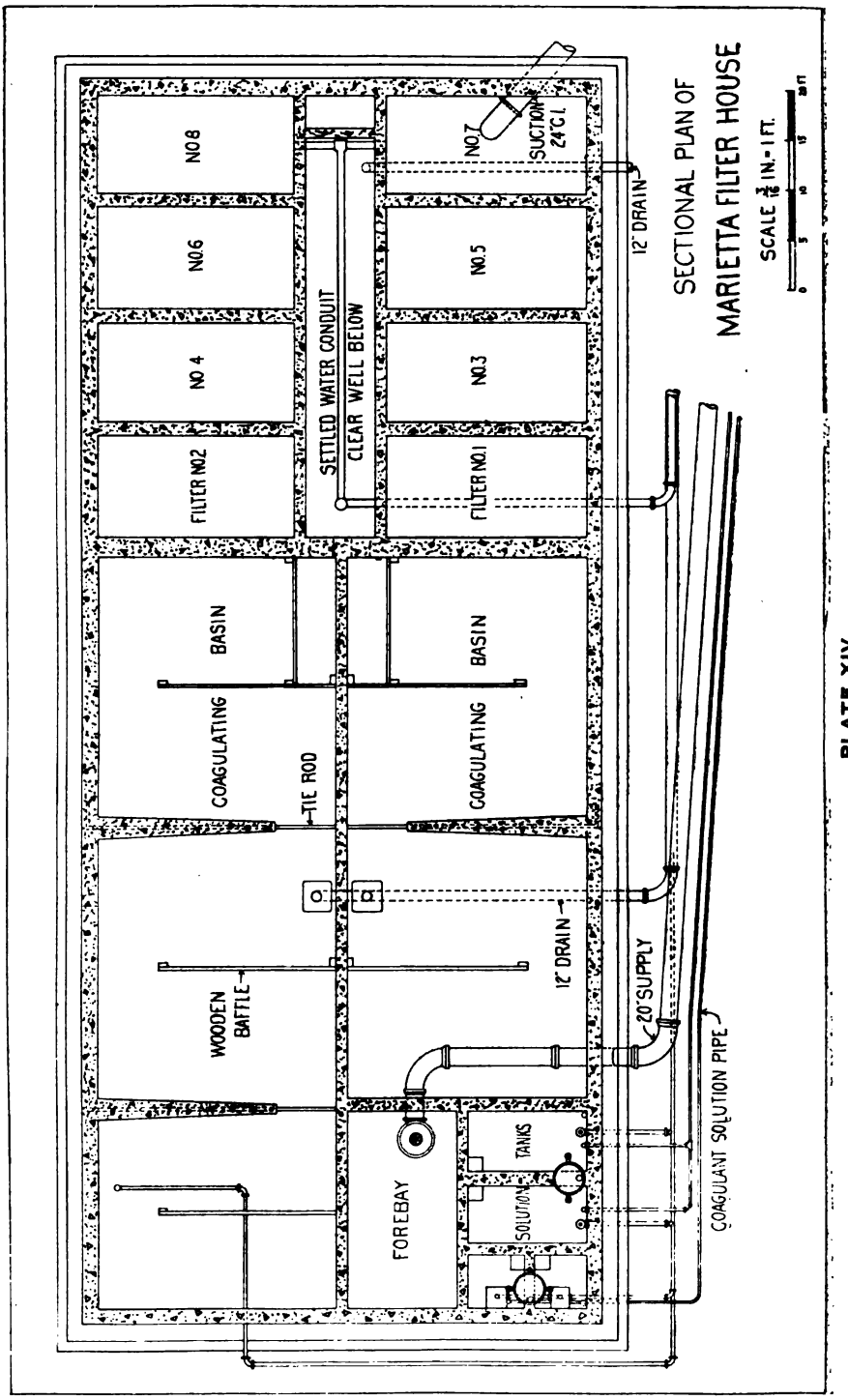

SECTIONAL PLAN OF
MARIETTA FILTER HOUSE
SCALE 1/8 IN. = 1 FT.
NO.8
NO.6
NO.4
FILTER NO.2
NO.7
SUCTION 24"CI
NO.5
NO.3
FILTER NO.1
SETTLED WATER CONDUIT
CLEAR WELL BELOW
12" DRAIN
BASIN
COAGULATING
TIE ROD
BASIN
COAGULATING
WOODEN BAFFLE
12" DRAIN
20" SUPPLY
FOREBAY
SOLUTION TANKS
COAGULANT SOLUTION PIPE

PLATE XIV.

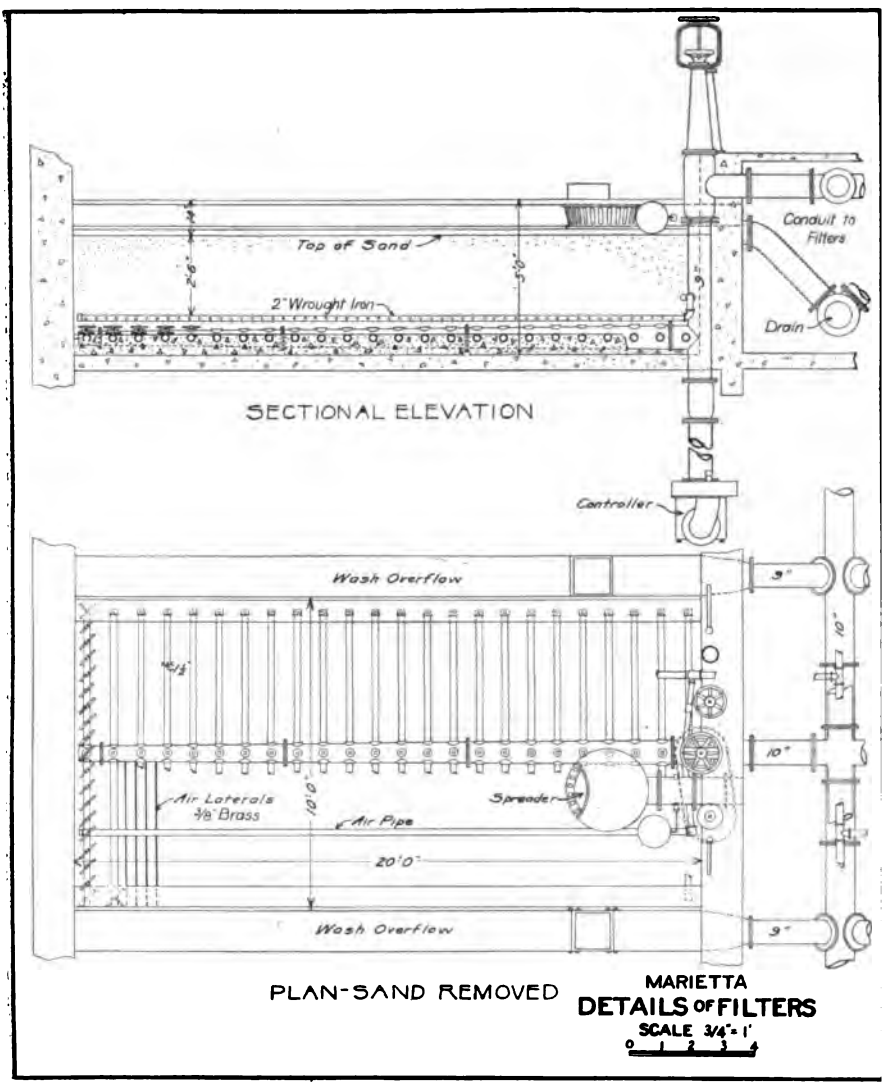

Top of Sand
2" Wrought Iron
Conduit to Filters
Drain
SECTIONAL ELEVATION
Controller
Wash Overflow
Air Laterals 1/8" Brass
Air Pipe
Spreader
20'0"
Wash Overflow
PLAN-SAND REMOVED
MARIETTA
DETAILS OF FILTERS
SCALE 3/4"=1'

PLATE XV.

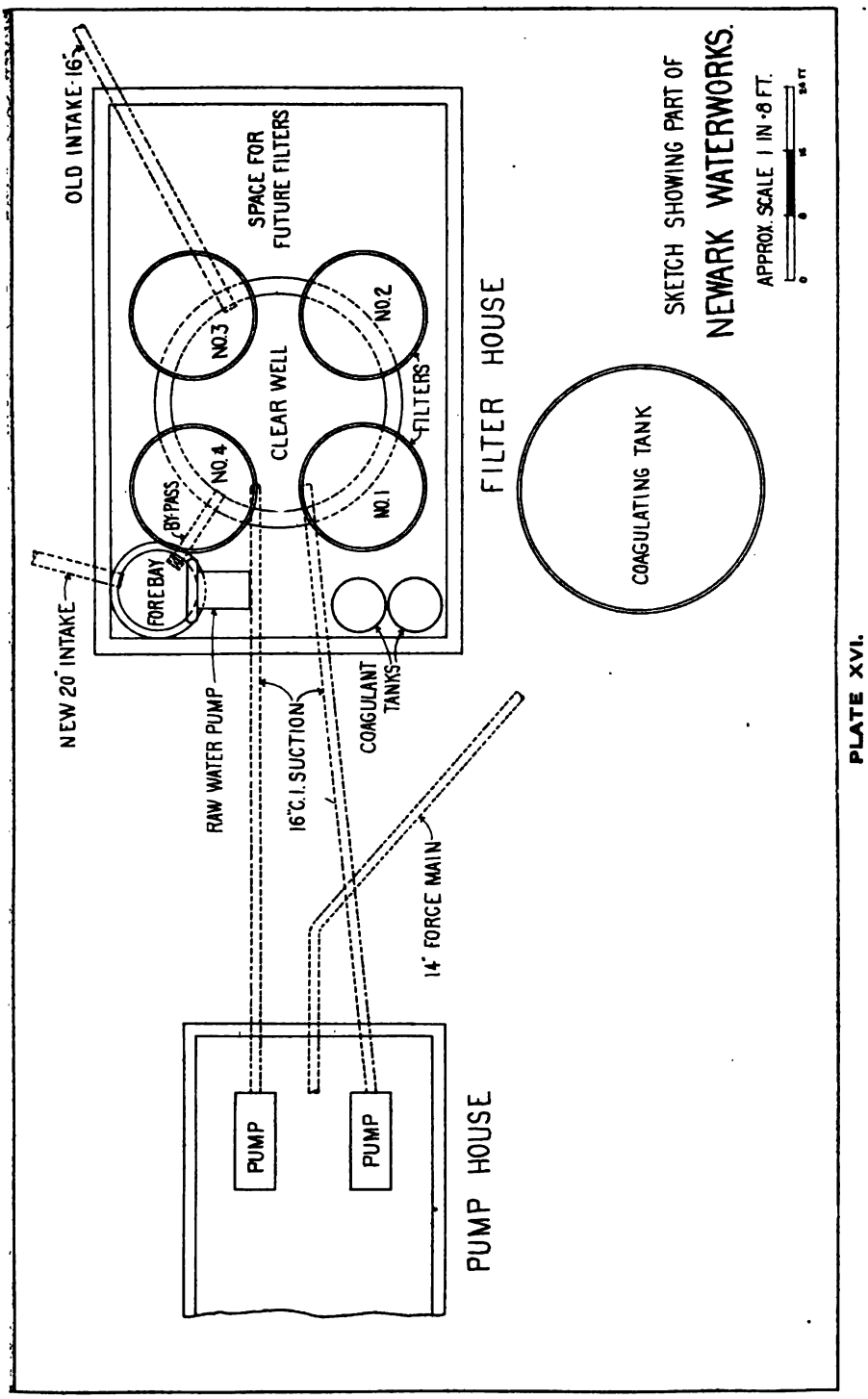

SKETCH SHOWING PART OF
NEWARK WATERWORKS.
APPROX. SCALE 1 IN 8 FT.
OLD INTAKE 16"
NEW 20" INTAKE
FOREBAY
BY-PASS
NO. 4
NO. 3
CLEAR WELL
NO. 2
NO. 1
FILTERS
SPACE FOR FUTURE FILTERS
FILTER HOUSE
COAGULATING TANK
RAW WATER PUMP
16" C. I. SUCTION
COAGULANT TANKS
14" FORCE MAIN
PUMP
PUMP
PUMP HOUSE

PLATE XVI.

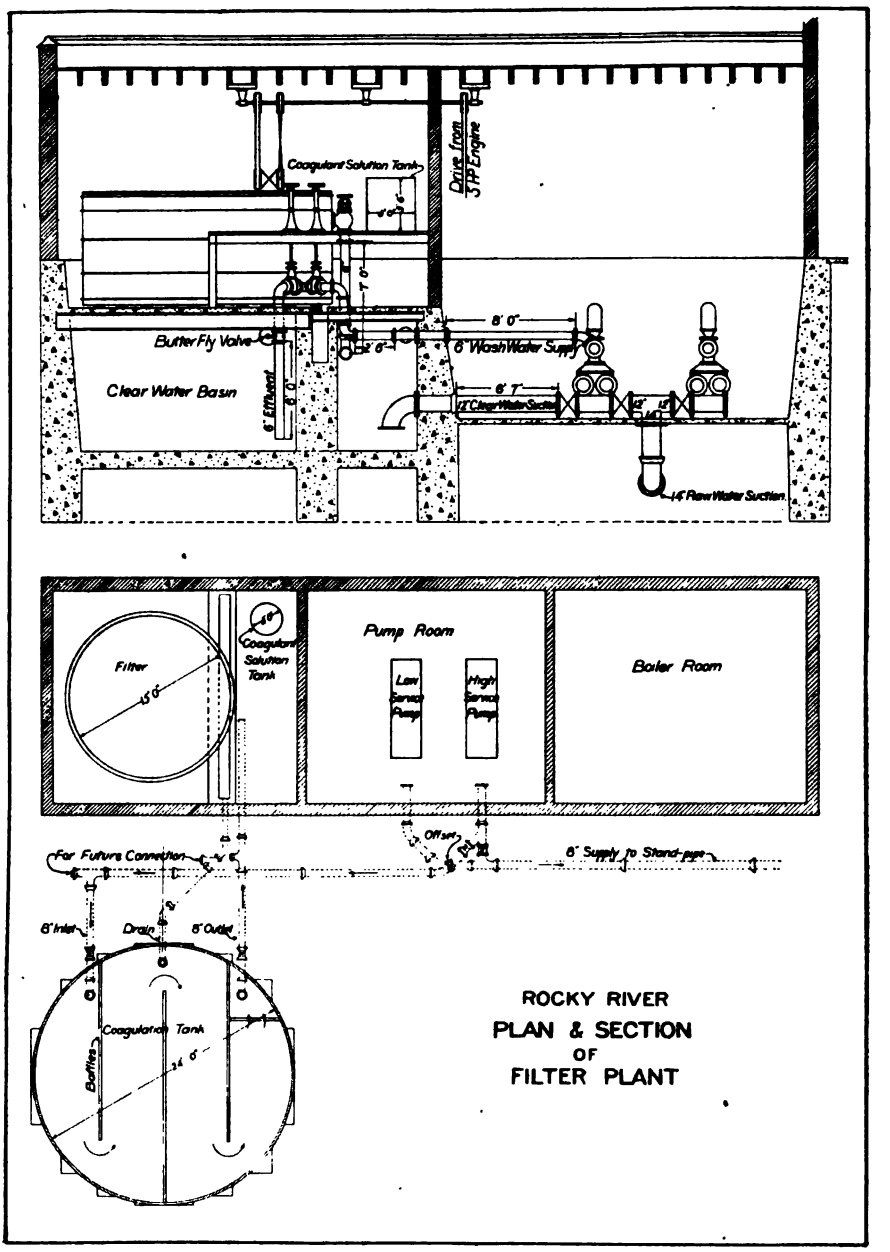

Coagulant Solution Tank
Drive from 3 HP Engine
Butter Fly Valve
Clear Water Basin
6" Effluent
6" Wash Water Supply
12" Clear Water Suction
14" Raw Water Suction
Filter
15'-0"
Coagulant Solution Tank
Pump Room
Low Service Pump
High Service Pump
Boiler Room
For Future Connection
Offset
6" Supply to Stand-pipe
6" Inlet
Drain
6" Outlet
Coagulation Tank
Baffles
14'-6"
ROCKY RIVER
PLAN & SECTION
OF
FILTER PLANT

PLATE XVII.

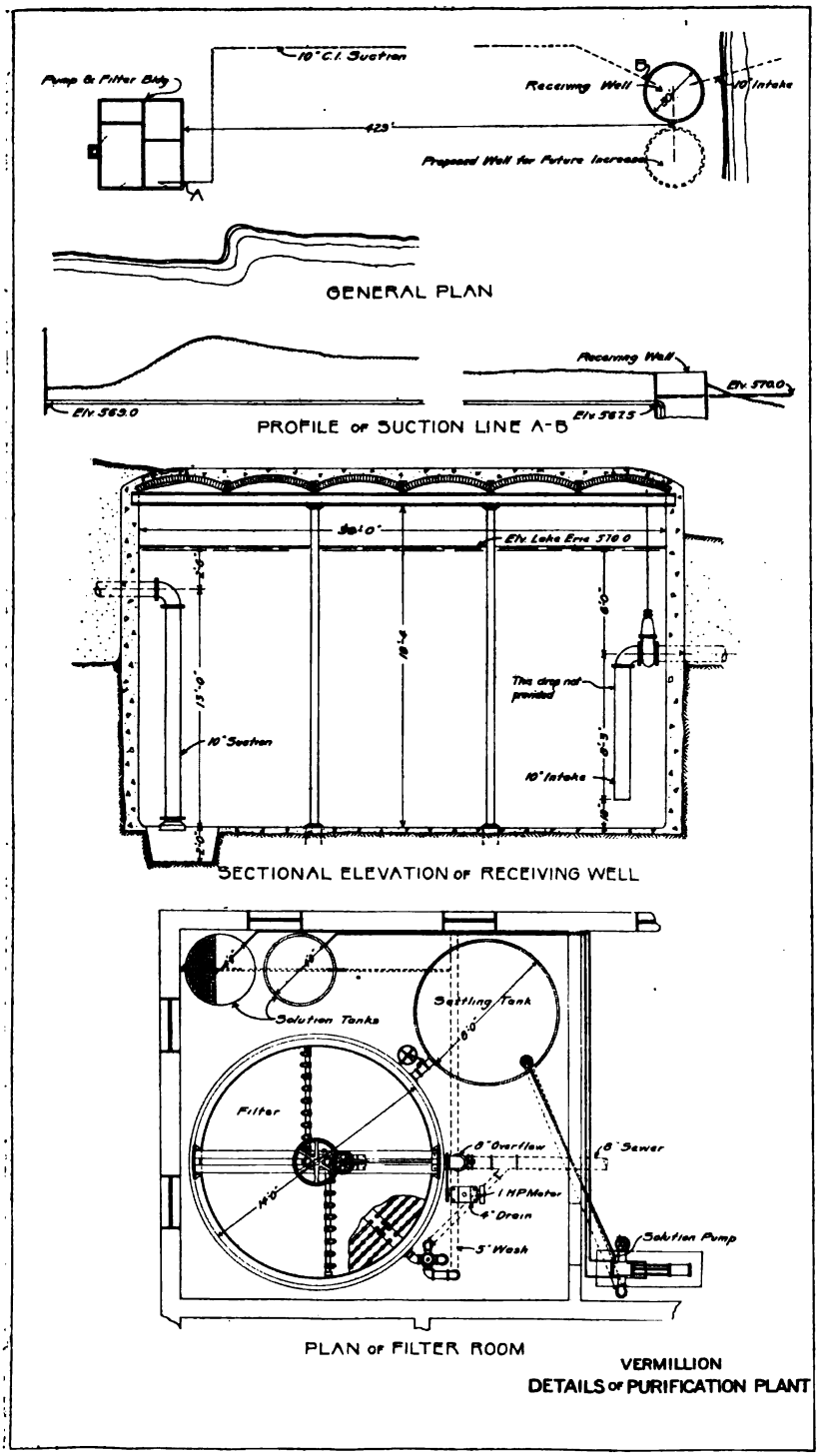
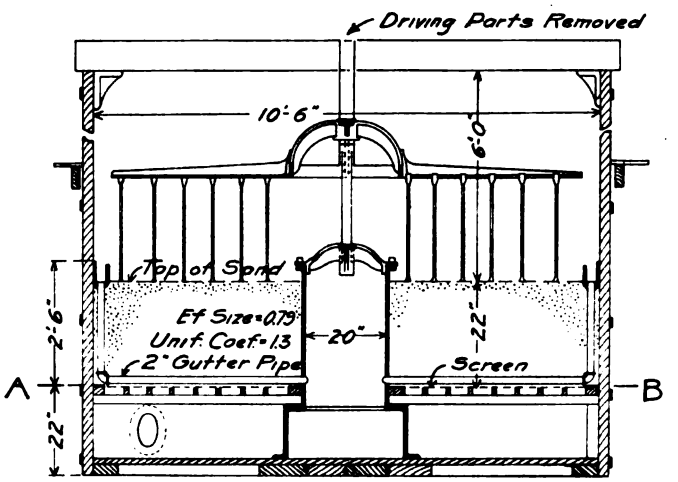
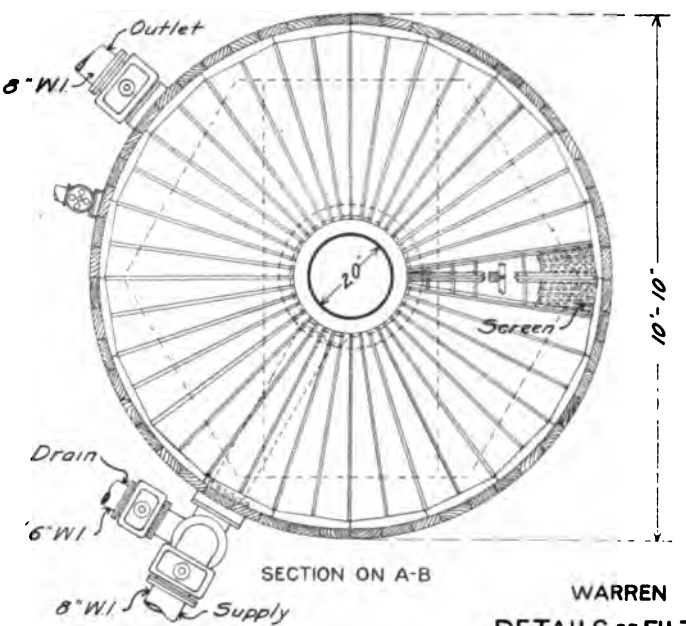

10" C.I. Suction
Pump & Filter Bldg
Receiving Well
10' Intake
425'
Proposed Well for Future Increase
GENERAL PLAN
Receiving Well
Elv. 576.0
Elv 563.0
Elv 567.5
PROFILE OF SUCTION LINE A-B
Sta 1.0"
Elv Lake Erie 576.0
10" Suction
This drop not provided
10" Intake
SECTIONAL ELEVATION OF RECEIVING WELL
Solution Tanks
Settling Tank
Filter
8" Overflow
8" Sewer
1 HP Motor
4" Drain
5" Wash
Solution Pump
PLAN OF FILTER ROOM
VERMILLION
DETAILS OF PURIFICATION PLANT

PLATE XVIII.



SECTIONAL ELEVATION



SECTION ON A-B

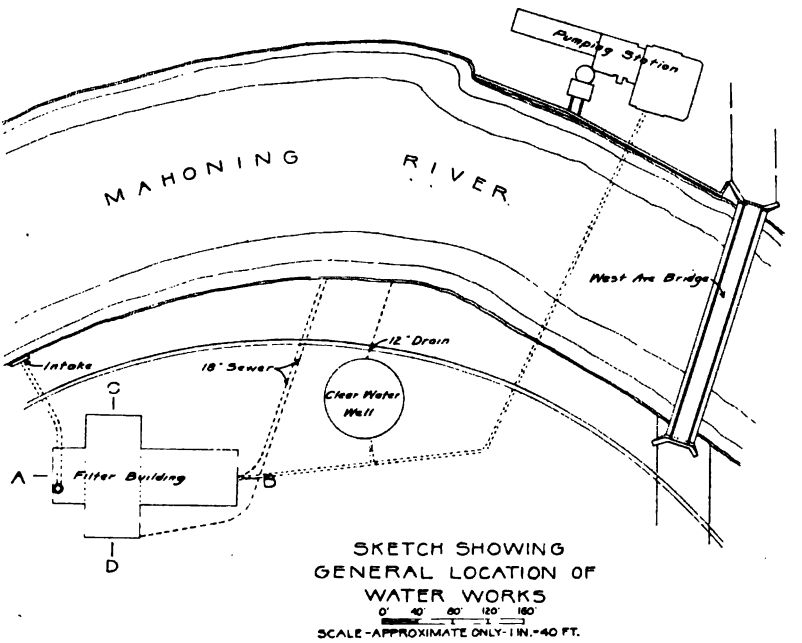
WARREN

DETAILS OF FILTER

SCALE 3/4"=1'

0 1 2 3 4

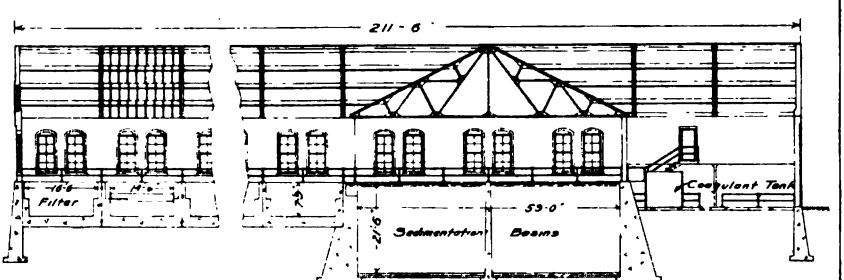
PLATE XIX.



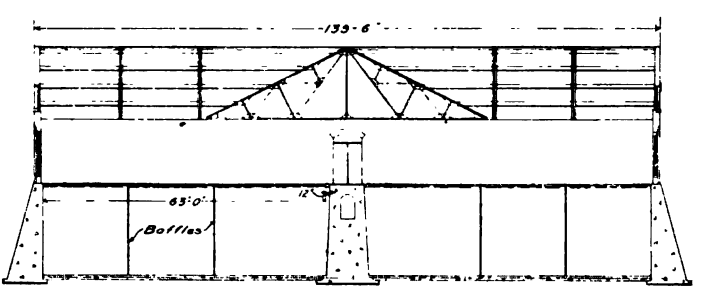
SKETCH SHOWING GENERAL LOCATION OF WATER WORKS

0' 40' 80' 120' 160'

SCALE - APPROXIMATE ONLY - 1 IN. = 40 FT.



SECTION ON A-B



SECTION ON C-D

YOUNGSTOWN

GENERAL PLAN OF WATER WORKS

SECTIONS THROUGH FILTER HOUSE

PLATE XX.

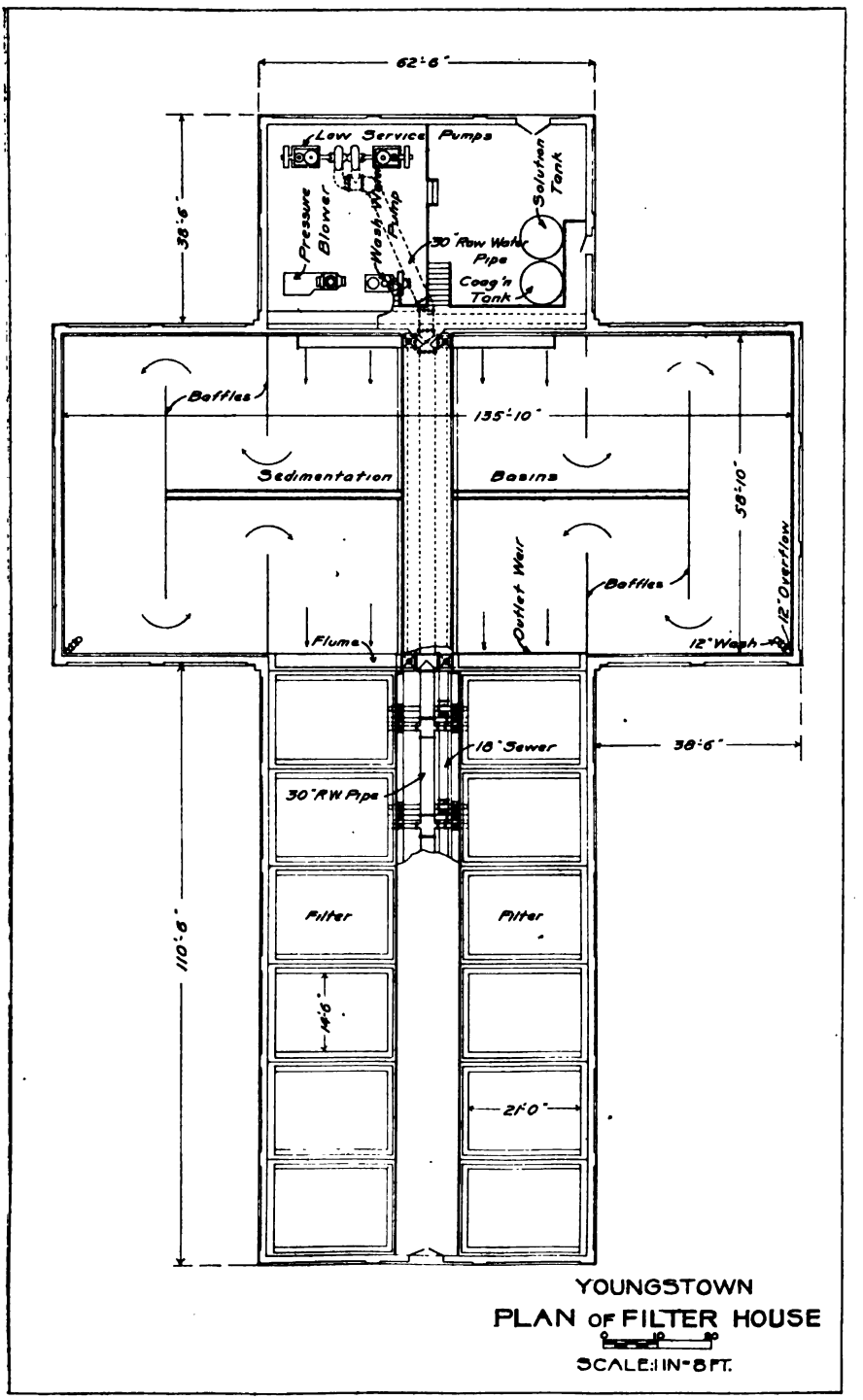
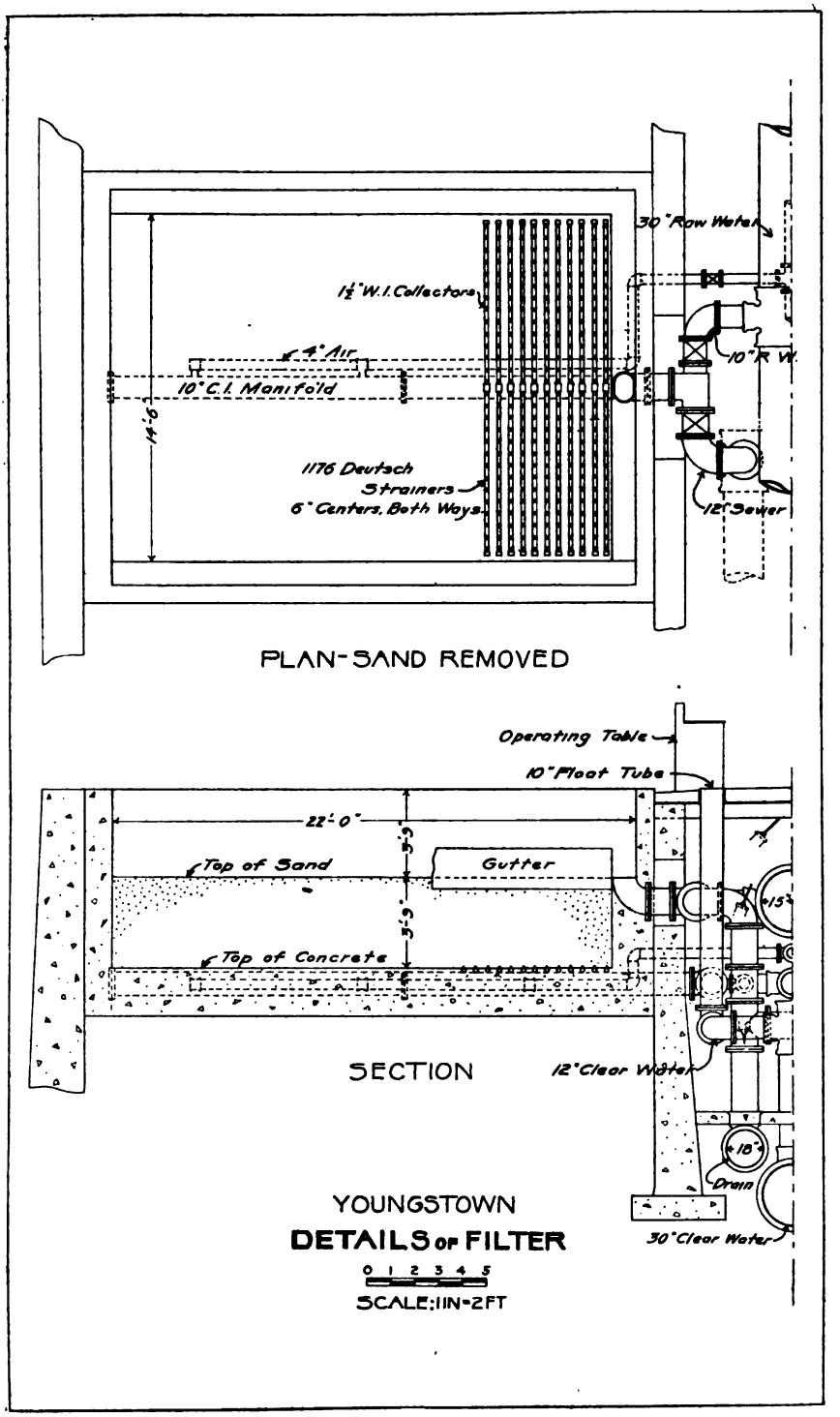
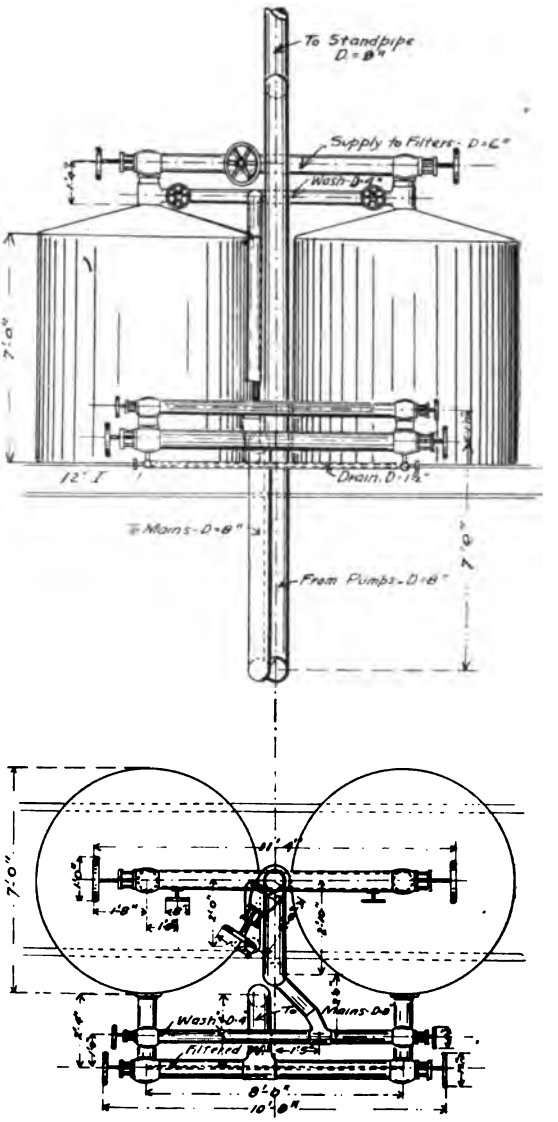

62'-6"
Low Service Pumps
Solution Tank
Pressure Blower
Wash-Water Pump
30" Raw Water Pipe
Coag'n Tank
38'-6"
Baffles
135'-10"
Sedimentation Basins
38'-10"
Outlet Weir
Baffles
12" Overflow
Flume
12" Wash
18" Sewer
38'-6"
30" R.W. Pipe
Filter
Filter
110'-6"
14'-6"
21'-0"
YOUNGSTOWN
PLAN OF FILTER HOUSE
SCALE: 1 IN = 8 FT.

PLATE XXI.


30" Raw Water
1½" W.I. Collectors
4" Air
10" C.I. Manifold
14'-0"
1176 Deutsch Strainers 6" Centers, Both Ways
10" R W
12" Sewer
PLAN-SAND REMOVED
Operating Table
10" Float Tube
22'-0"
3'-3"
3'-3"
Top of Sand
Gutter
Top of Concrete
SECTION
12" Clear Water
Drain
30" Clear Water
YOUNGSTOWN
DETAILS OF FILTER
0 1 2 3 4 5
SCALE: 1 IN = 2 FT



Elevation and Plan of Pressure Filters at Oberlin, O.

PLATE XXIII.

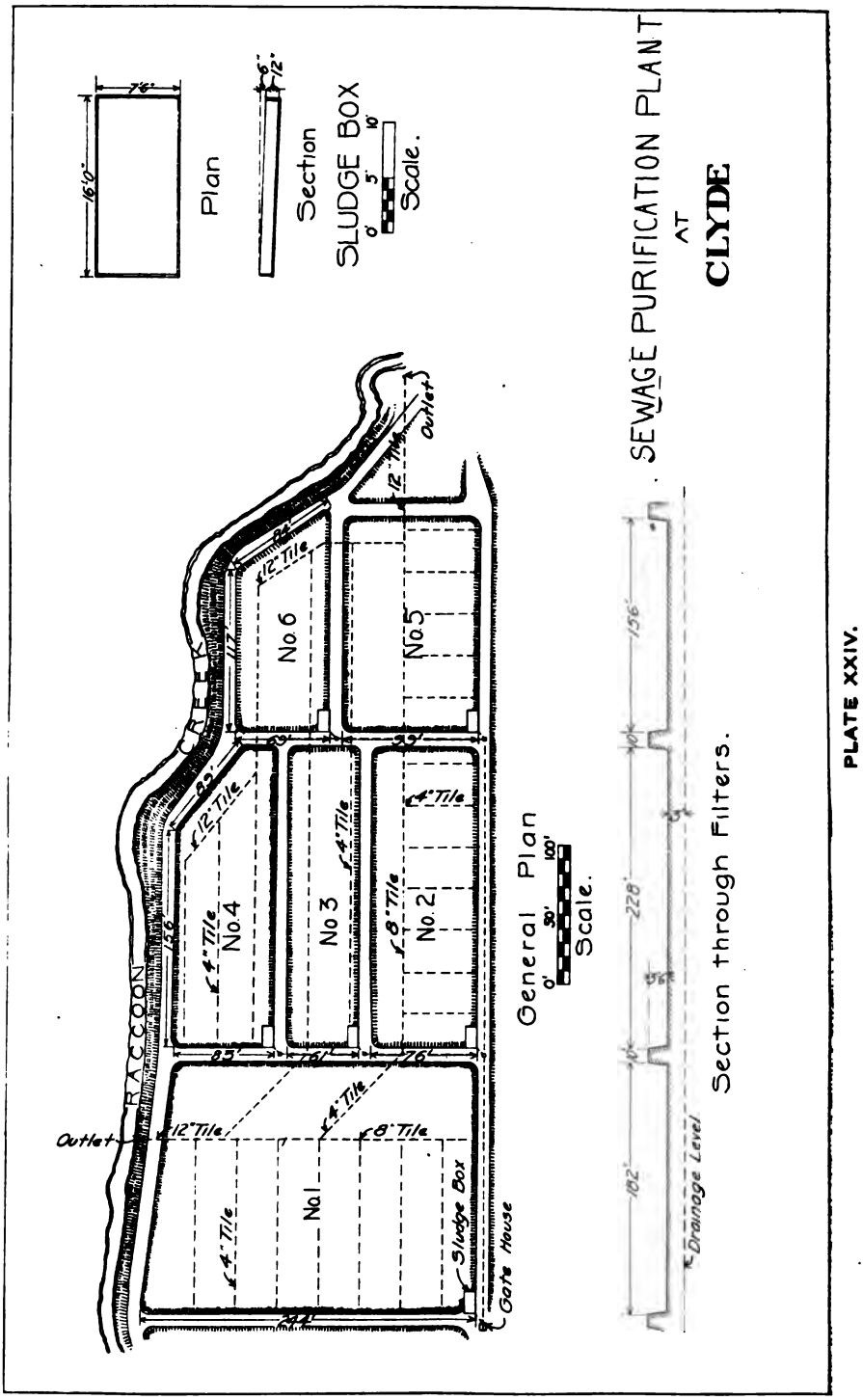

SEWAGE PURIFICATION PLANT
AT
CLYDE
Plan
Section
SLUDGE BOX
Scale.
General Plan
Scale.
Section through Filters.
RACCOON CREEK
No 1
No 2
No 3
No 4
No 5
No 6
Outlet
Sludge Box
Gate House
Drainage Level

PLATE XXIV.

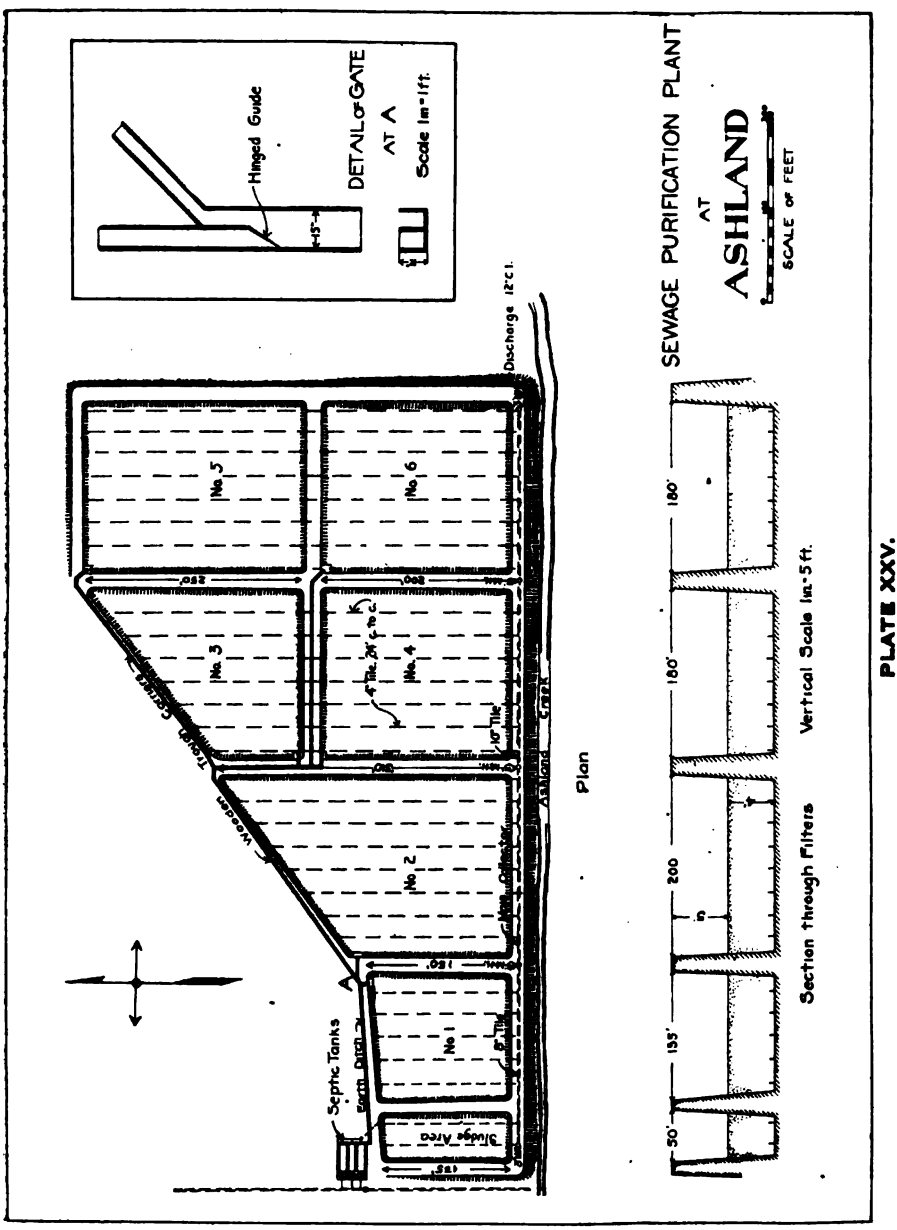

SEWAGE PURIFICATION PLANT
AT
ASHLAND
SCALE OF FEET
DETAIL OF GATE
AT A
Scale 1in=1ft.
Hinged Guide
Discharge 12"CI.
No. 1
No. 2
No. 3
No. 4
No. 5
No. 6
Septic Tanks
Sludge Area
Plan
Section through Filters
Vertical Scale 1in=5ft.

PLATE XXV.

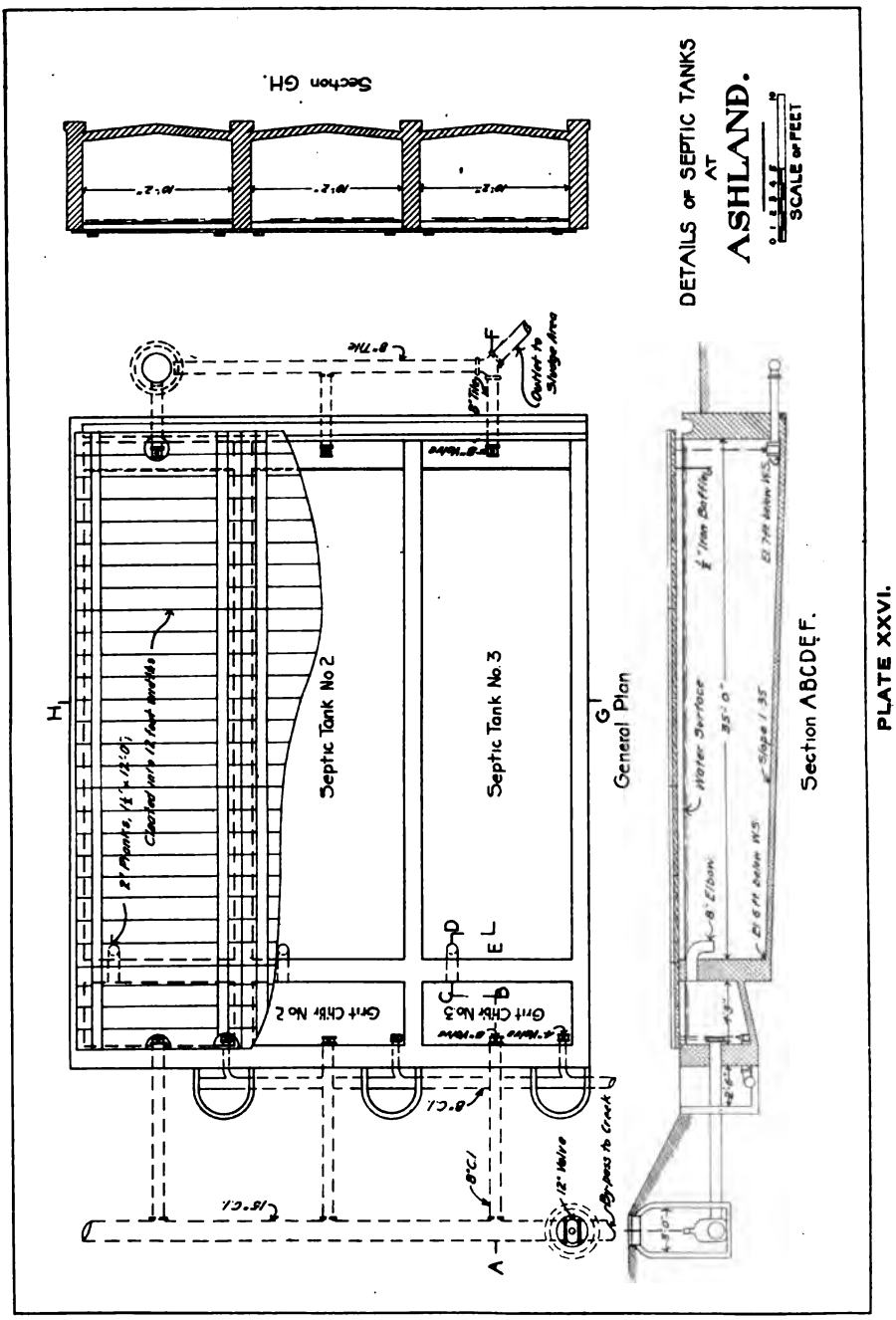

DETAILS OF SEPTIC TANKS AT ASHLAND.
SCALE OF FEET
Section GH.
Septic Tank No 2
Septic Tank No 3
Grit Chbr No 2
Grit Chbr No 3
General Plan
Section ABCDEF.

PLATE XXVI.

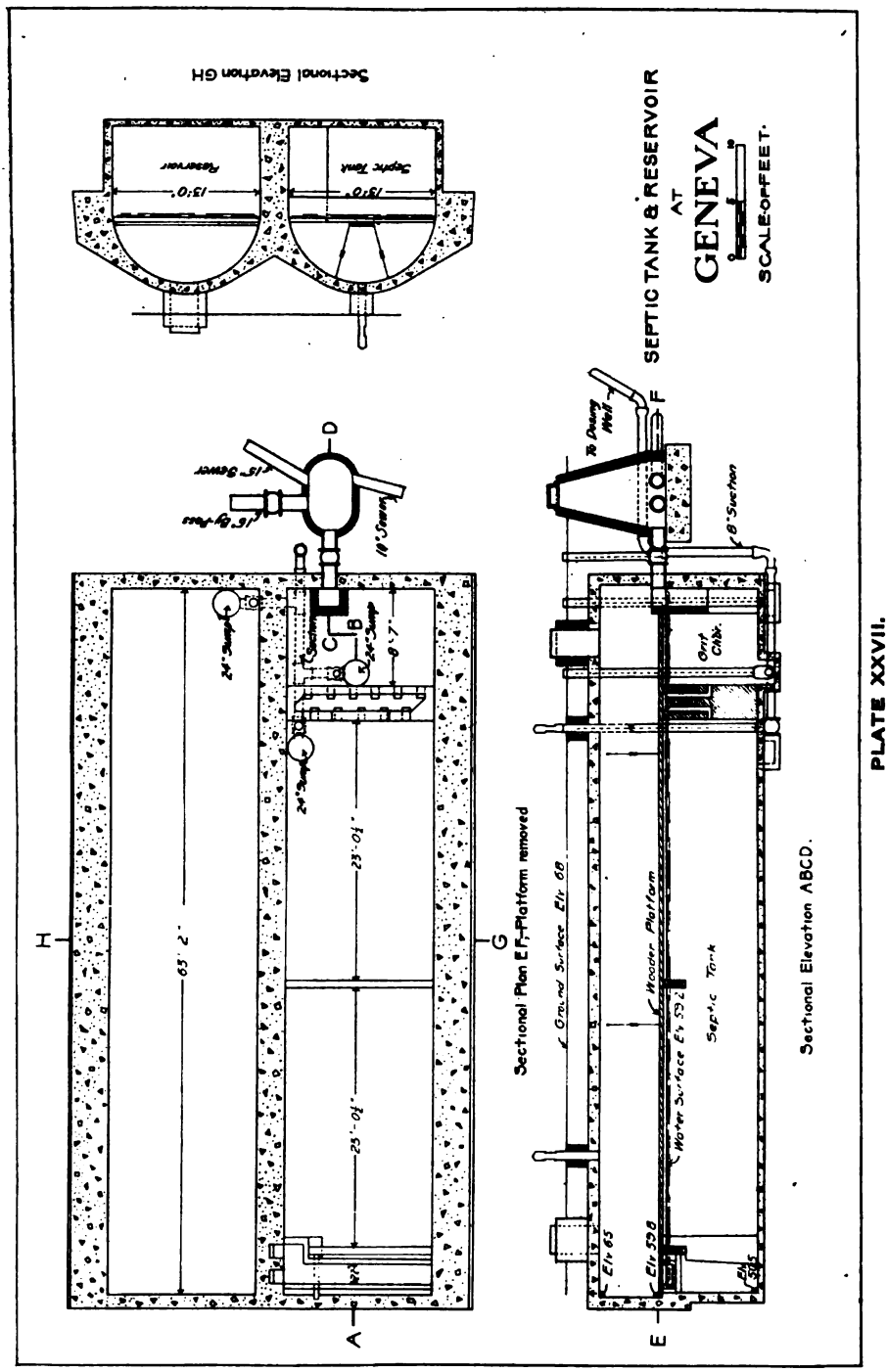

SEPTIC TANK & RESERVOIR
AT
GENEVA
SCALE-OF-FEET
Sectional Elevation GH
Septic Tank
Reservoir
15'-0"
15'-0"
Sectional Plan EF-Platform removed
Sectional Elevation ABCD.
Ground Surface Elv 68
Wooden Platform
Water Surface Elv 59.2
Septic Tank
Elv 59.0
Elv 65
Elv 58.5
To Dump Well
8" Suction
Over Chlx.
65'-2"
23'-04"
23'-04"
24" Sump
24" Sump
24" Sump
15" Sewer
15" By-Pass
18" Sewer
A
B
C
D
E
F
G
H

PLATE XXVII.

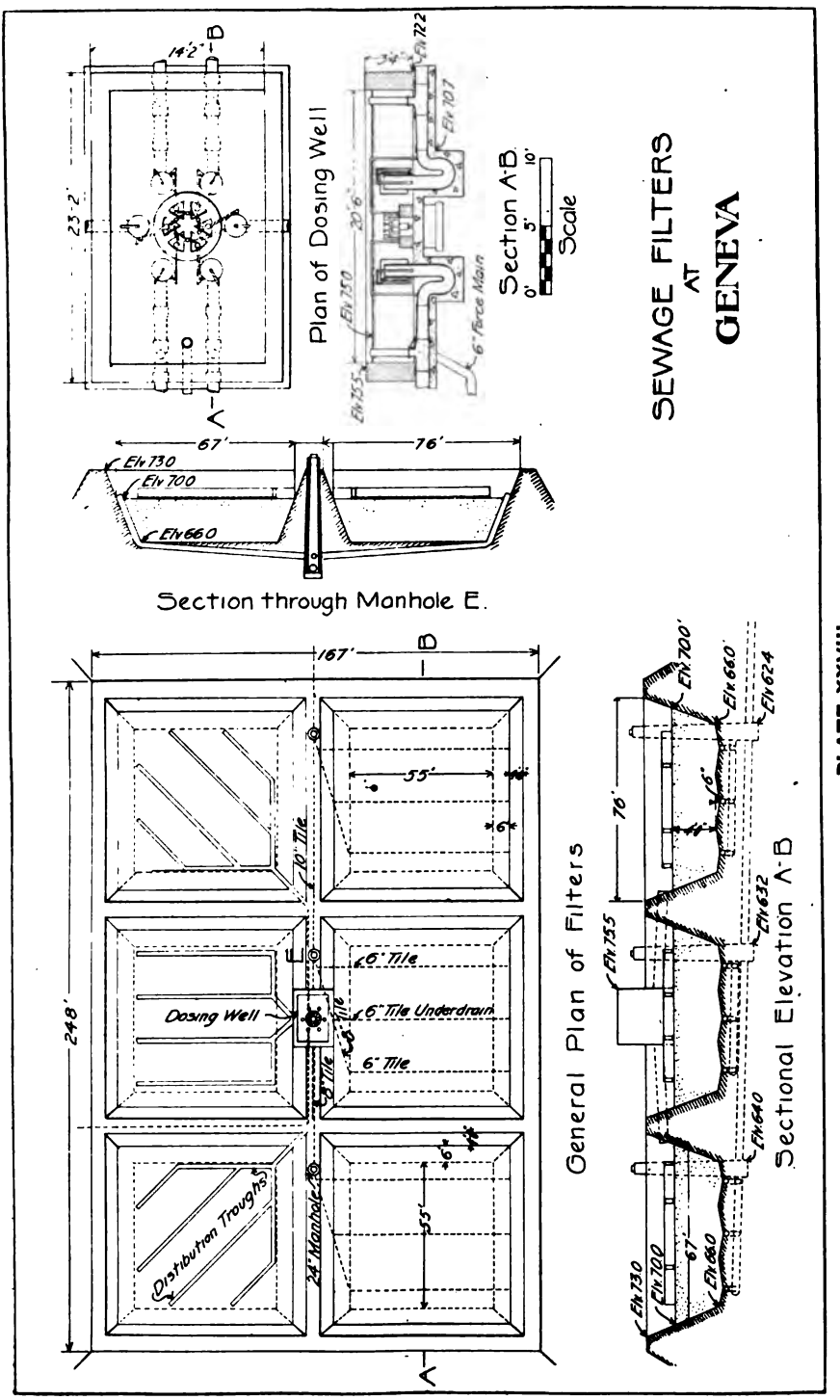


PLATE XXVIII.

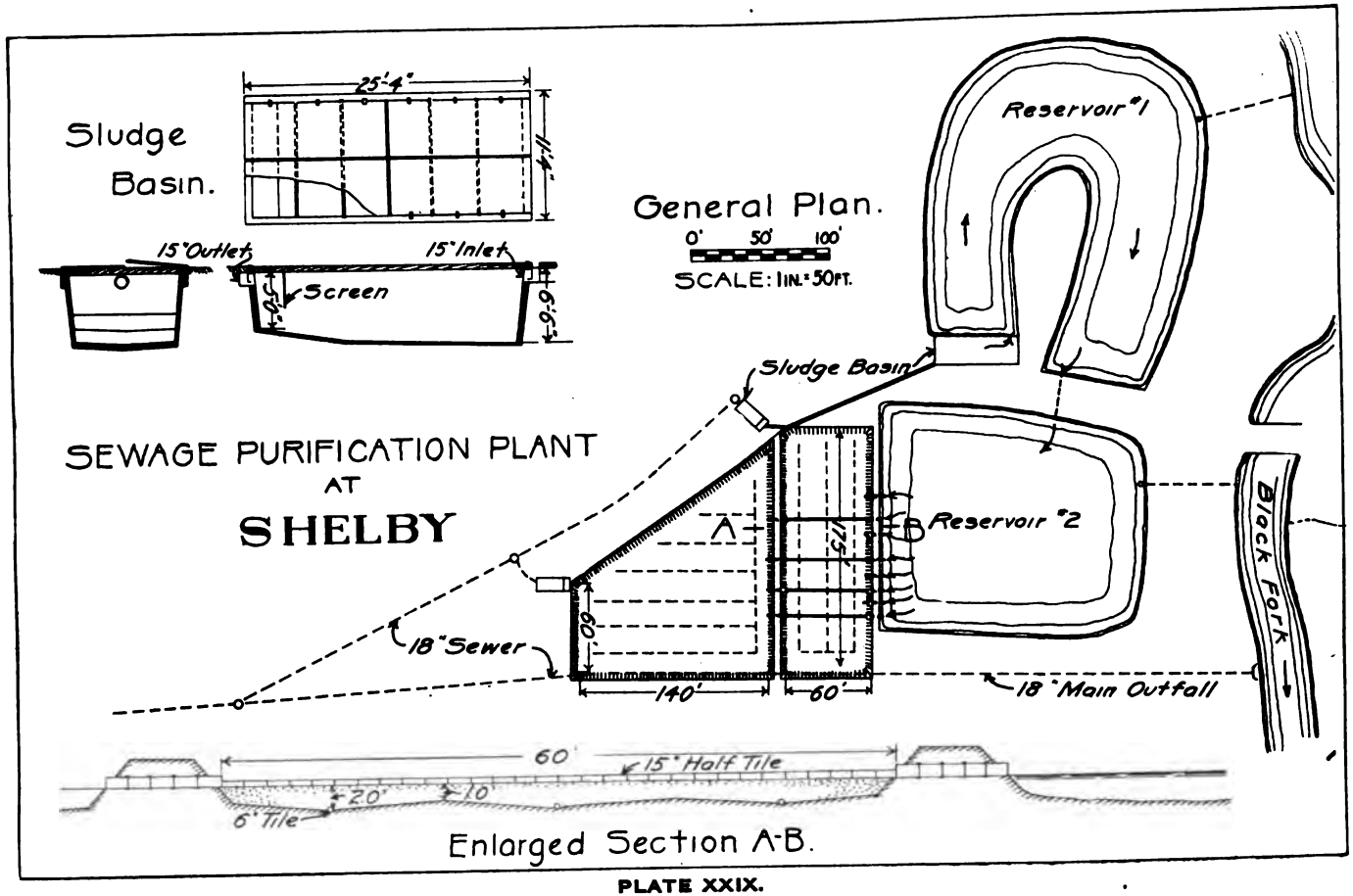

Sludge Basin.
25'-4"
11'-4"
15" Outlet
15" Inlet
Screen
5'-6"
6'-6"
General Plan.
0' 50' 100'
SCALE: 1 IN. = 50 FT.
Reservoir "1
Sludge Basin
SEWAGE PURIFICATION PLANT
AT
SHELBY
A
B
175'
60'
Reservoir "2
Black Fork
18" Sewer
140'
60'
18" Main Outfall
60'
15" Half Tile
20'
10'
6" Tile
Enlarged Section A-B.

PLATE XXIX.

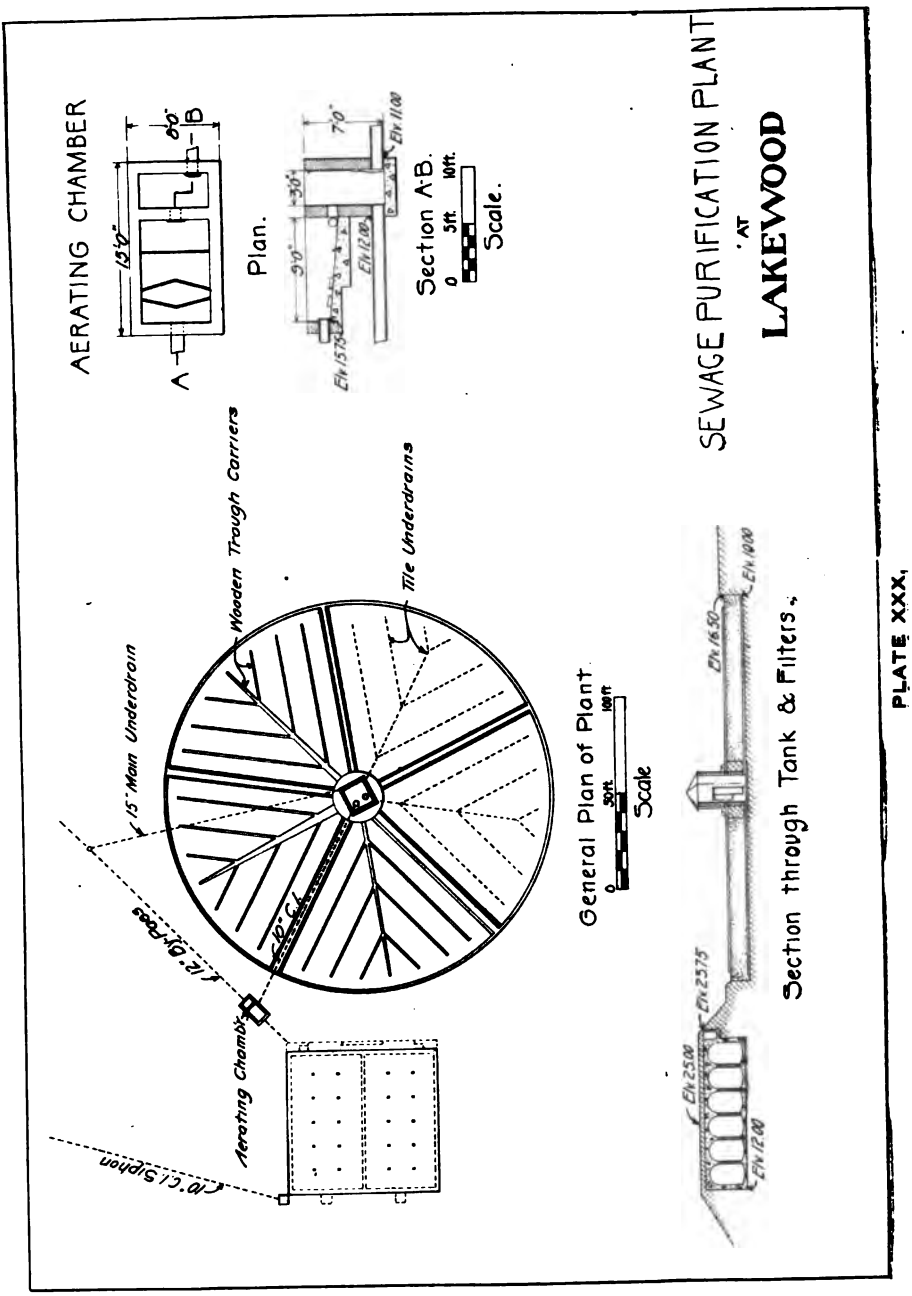

AERATING CHAMBER
15'0"
6'0"
A
B
Plan.
7'0"
3'0"
3'0"
EN 11.00
EN 12.00
EN 13.50
Section A-B.
0 5ft. 10ft.
Scale.
SEWAGE PURIFICATION PLANT
AT
LAKEWOOD
Wooden Trough Carriers
Tile Underdrains
15" Main Underdrain
12" C.I.
Aerating Chamber
12" C.I. Siphon
General Plan of Plant
0 30ft. 60ft.
Scale
EN 16.50
EN 10.00
EN 25.75
EN 25.00
EN 12.00
Section through Tank & Filters.

PLATE XXX.

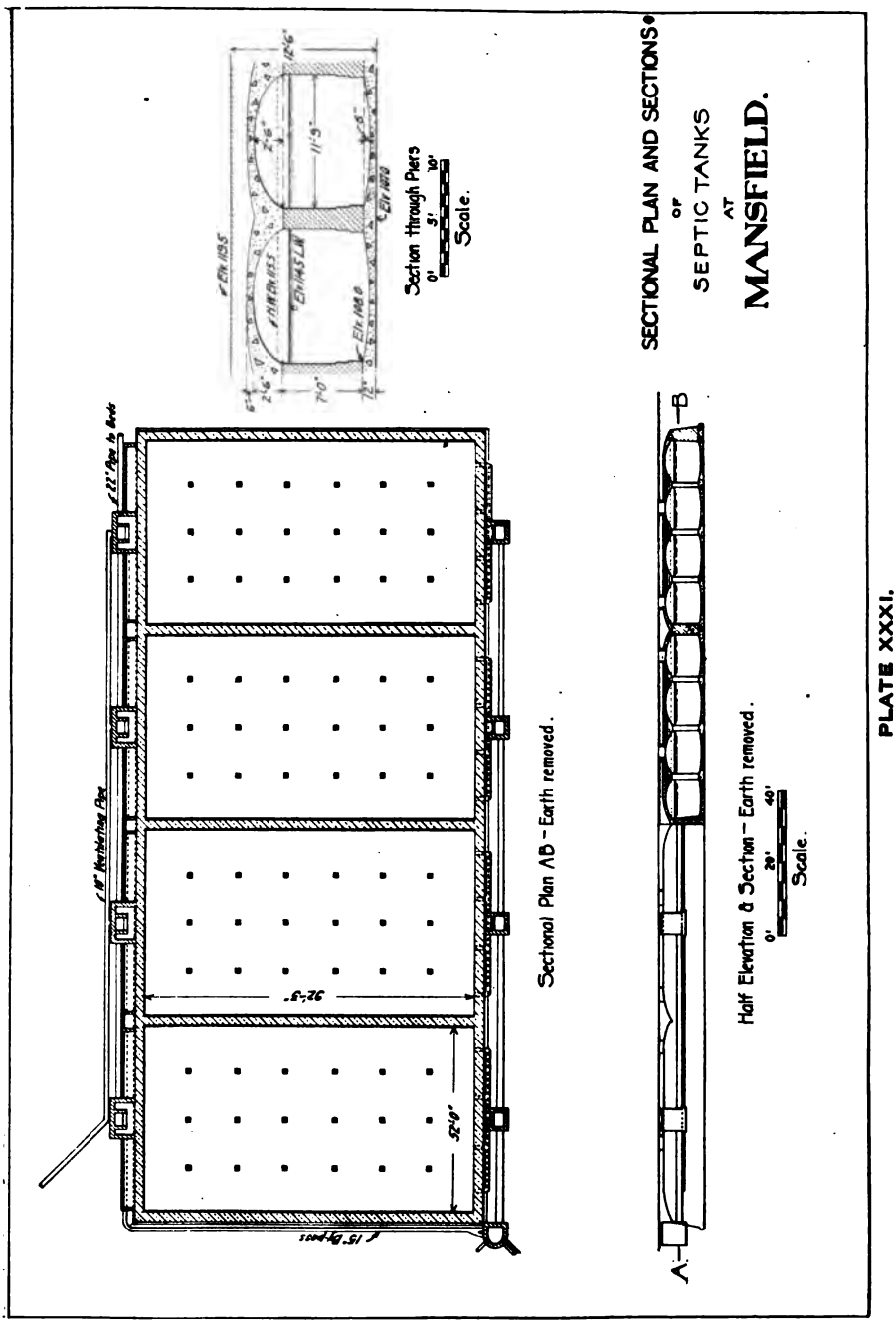

SECTIONAL PLAN AND SECTIONS
OF
SEPTIC TANKS
AT
MANSFIELD.
Section through Piers
0' 5' 10'
Scale.
Sectional Plan AB - Earth removed.
Half Elevation & Section - Earth removed.
0' 20' 40'
Scale.
A
B
92'-3"
52'-0"

PLATE XXXI.

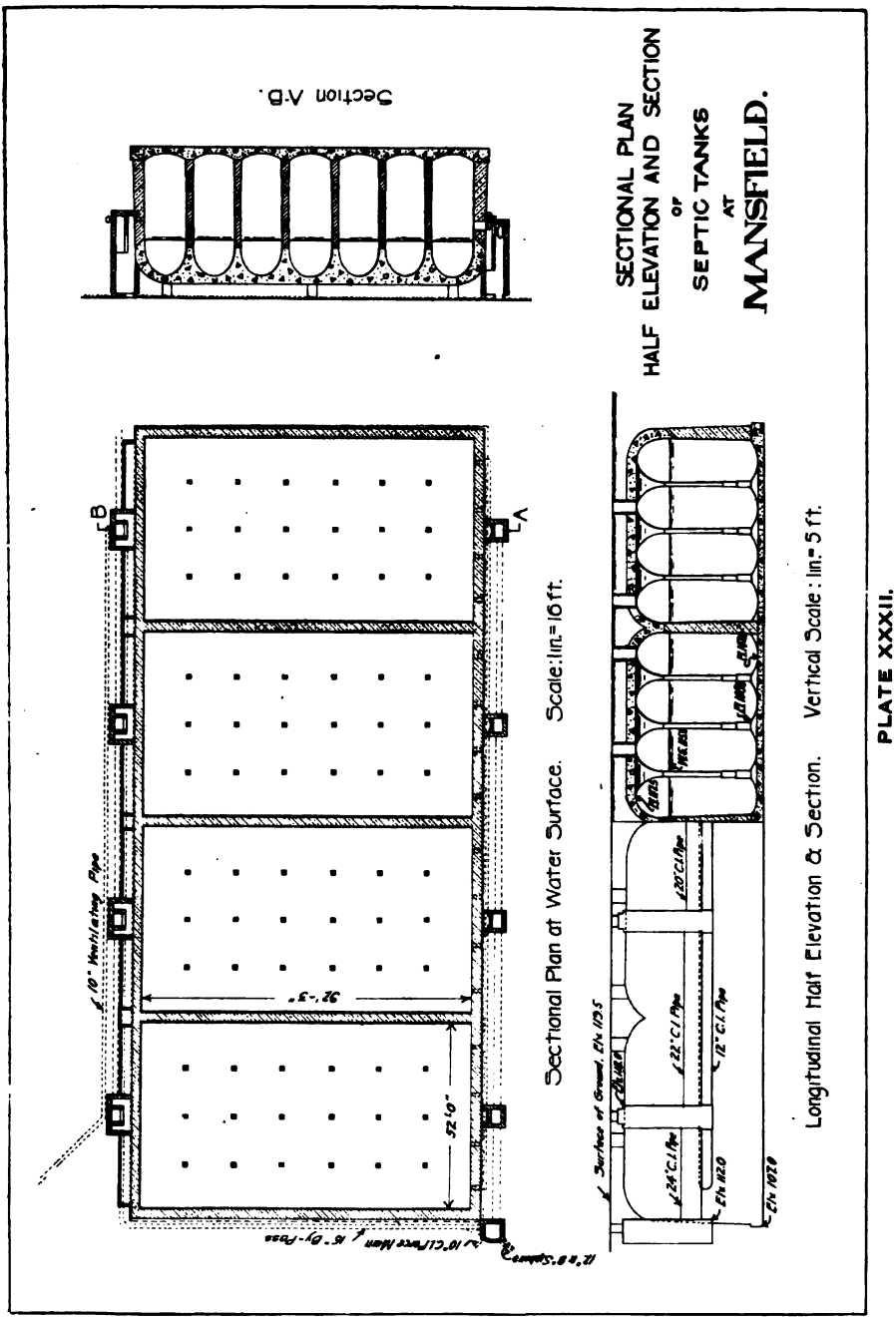

SECTIONAL PLAN
HALF ELEVATION AND SECTION
OF
SEPTIC TANKS
AT
MANSFIELD.
Section A-B.
Sectional Plan at Water Surface. Scale: 1in.=16ft.
Longitudinal Half Elevation & Section. Vertical Scale: 1in.= 5 ft.
Surface of Ground. Elv. 113.5
Elv. 112.0
Elv. 107.0
A
B

PLATE XXXII.

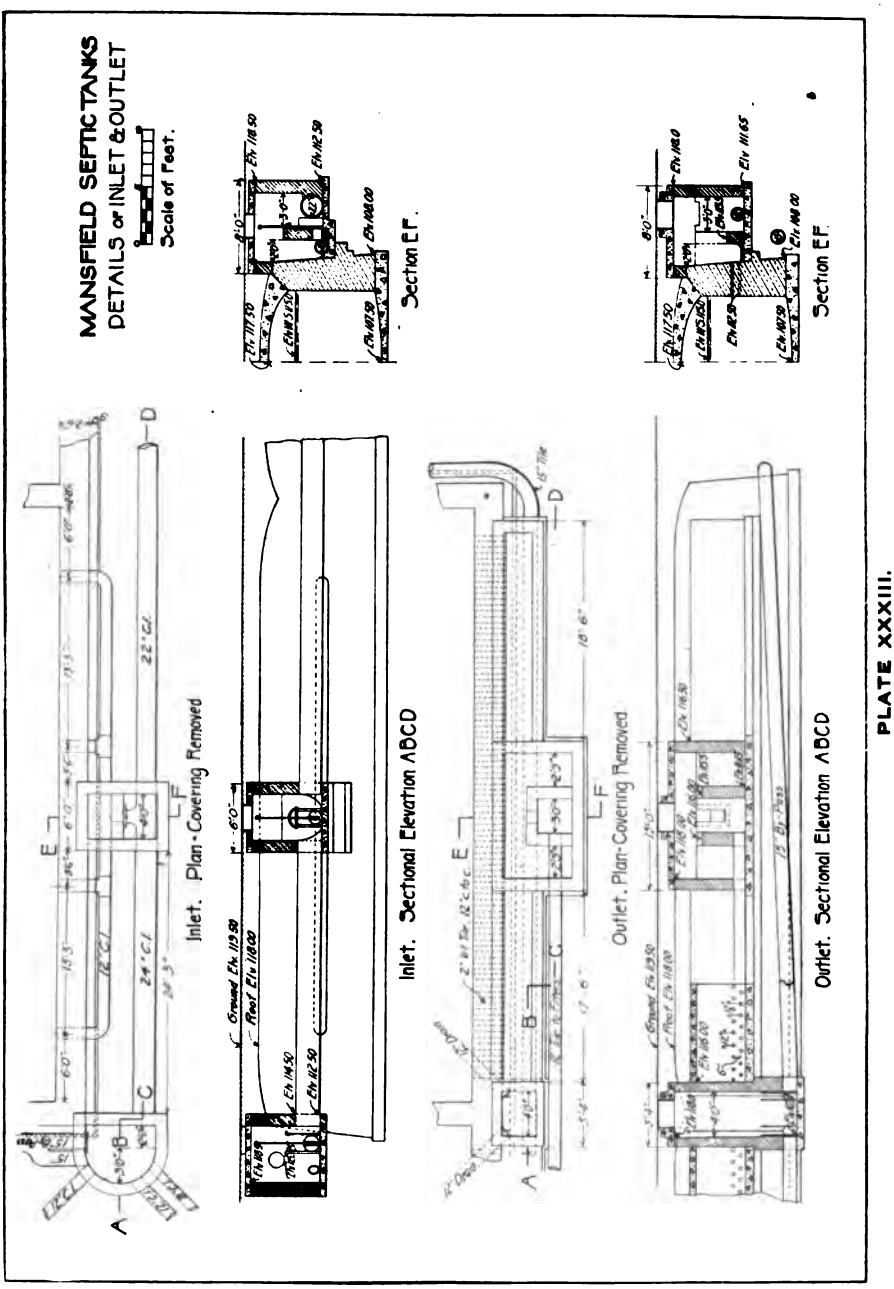


PLATE XXXIII.

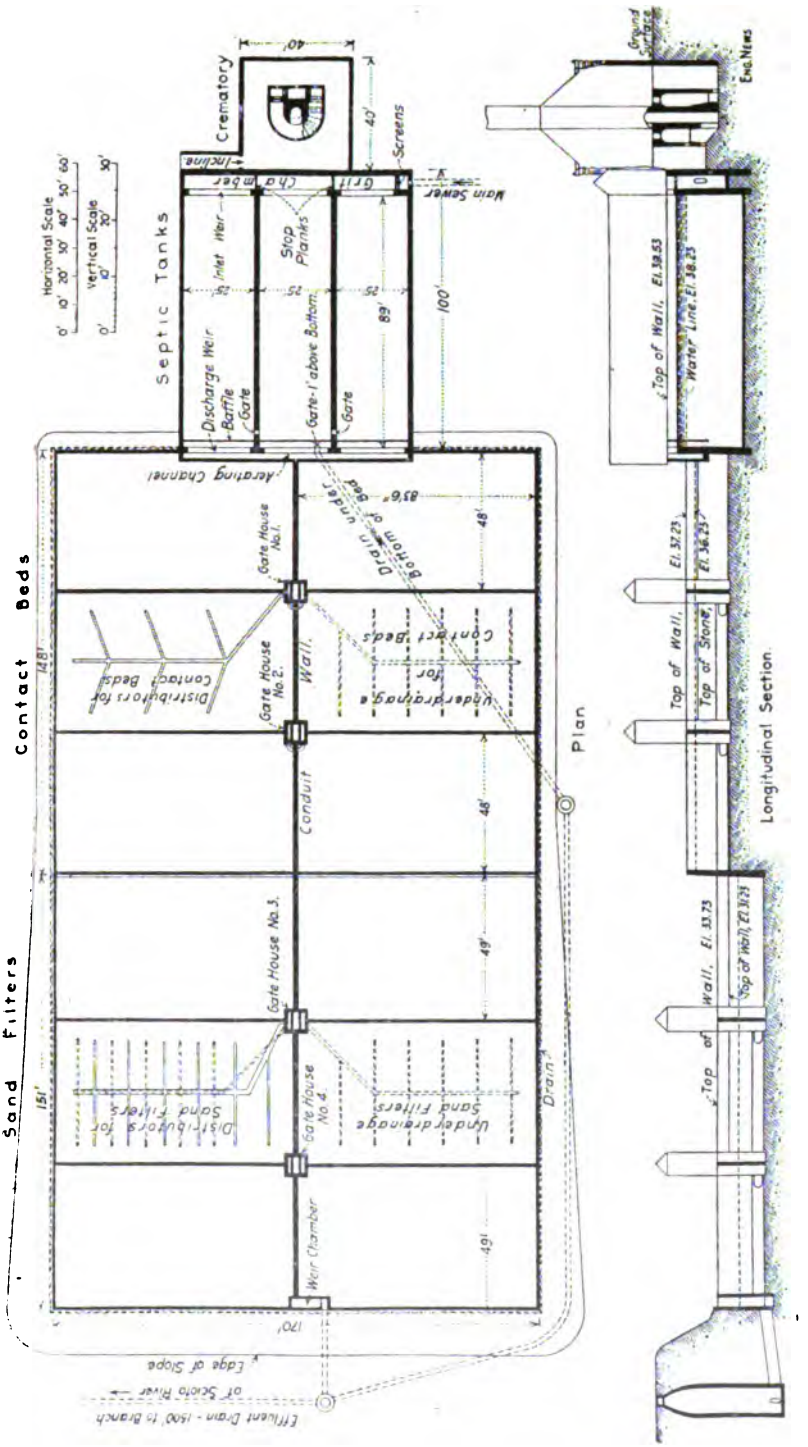


FIG. 1. PLAN, LONGITUDINAL SECTION AND DETAILS OF SEWAGE AND GARBAGE DISPOSAL PLANT, MARION, O.

PLATE XXXIV.

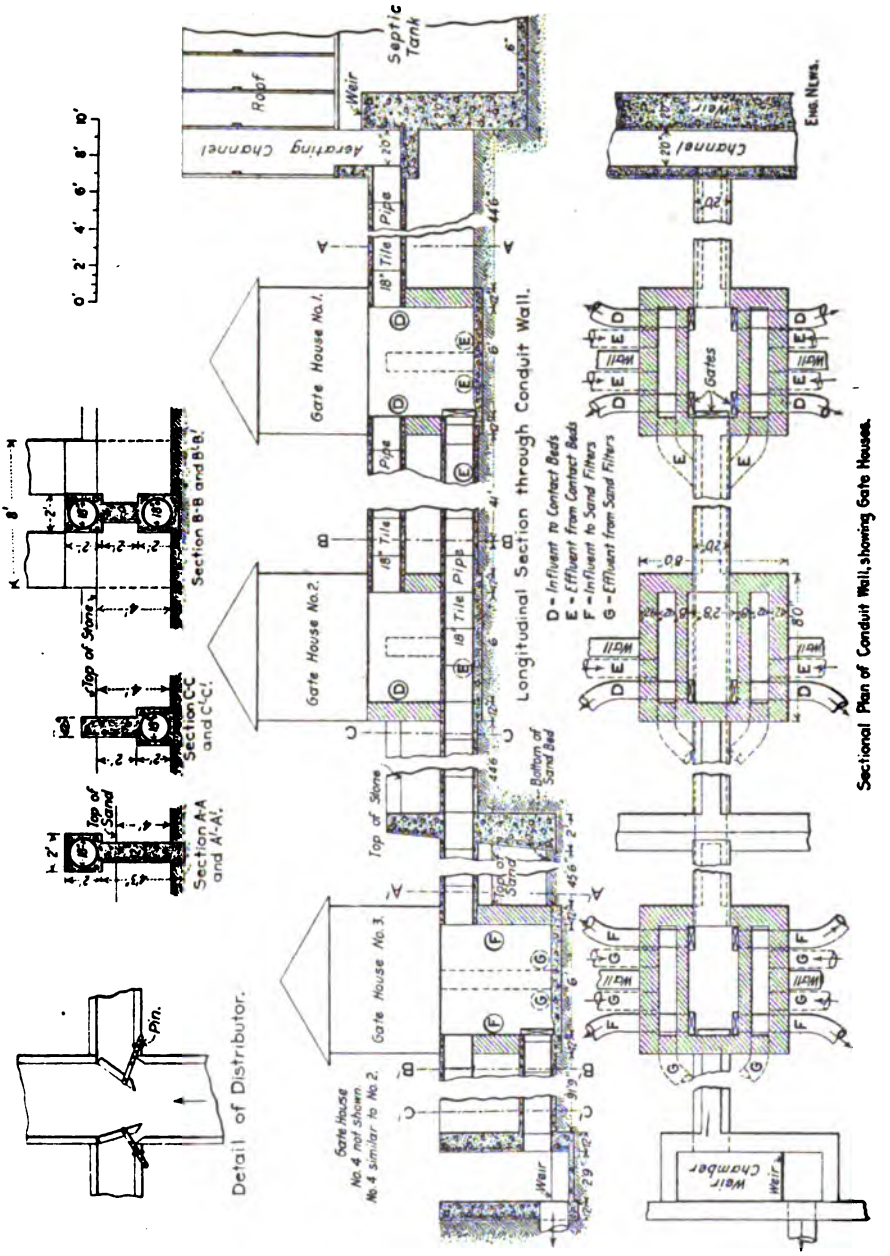

Septic Tank
Weir
Roof
Aerating Channel
Gate House No.1.
Gate House No.2.
Gate House No.3.
Gate House No.4 not shown. No.4 similar to No.2.
Pipe
18" Tile
Top of Stone
Bottom of Sand Bed
Top of Sand
Weir
Weir Chamber
Channel
Gates
End Weirs
D - Influent to Contact Beds
E - Effluent from Contact Beds
F - Influent to Sand Filters
G - Effluent from Sand Filters
Longitudinal Section through Conduit Wall.
Sectional Plan of Conduit Wall, showing Gate Houses.
Section A-A and A'-A'.
Section C-C and C'-C'.
Section B-B and B'-B'.
Detail of Distributor.
Pin.

PLATE XXXV.

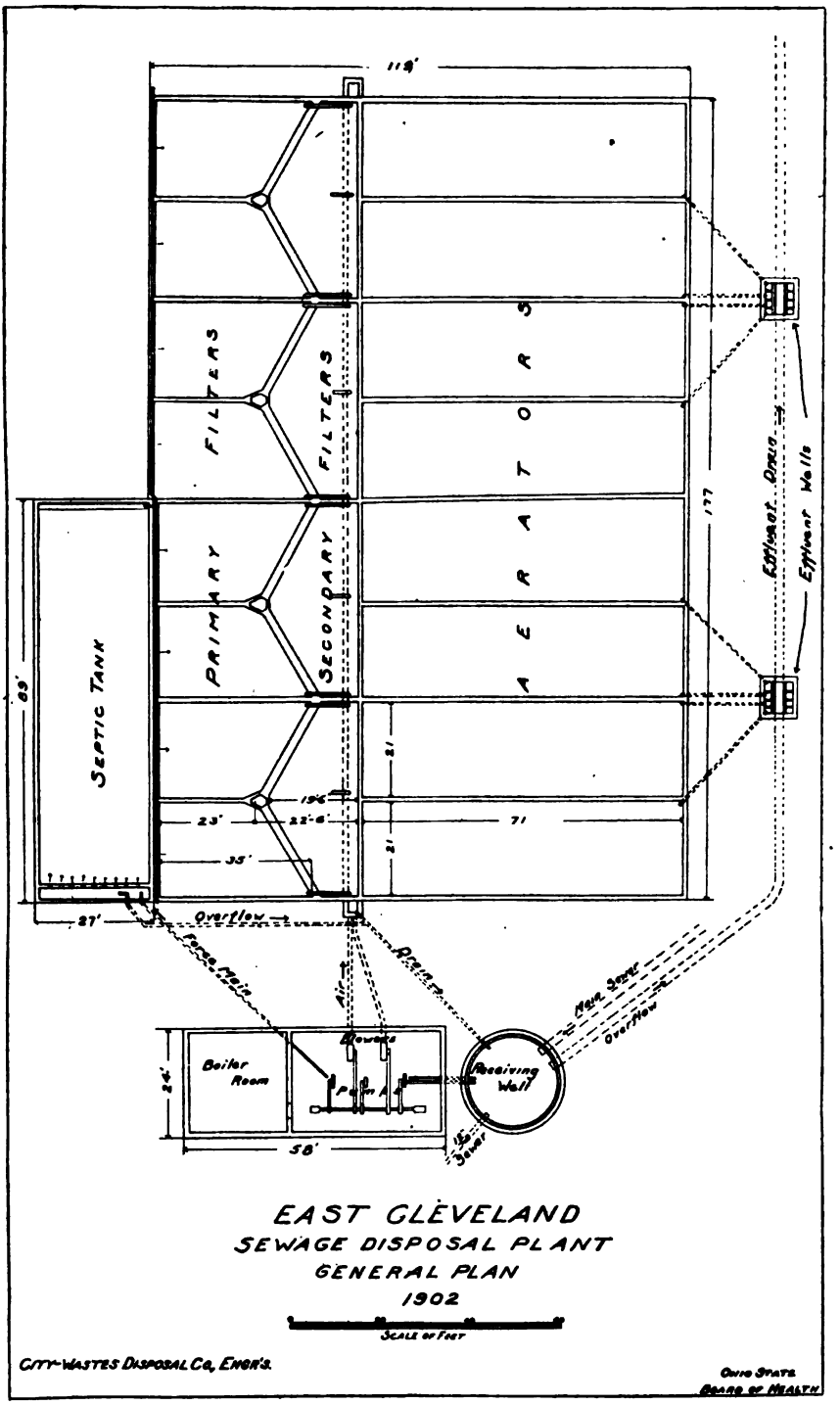

119'
AERATORS
177
Effluent Ditch
Effluent Weir
SECONDARY FILTERS
PRIMARY FILTERS
SEPTIC TANK
83'
21'
19'6"
23'
22'6"
71'
35'
27'
Overflow
Force Main
Air
Sewage
Main Sewer
Overflow
Boiler Room
Blowers
Receiving Well
24'
58'
EAST CLEVELAND
SEWAGE DISPOSAL PLANT
GENERAL PLAN
1902
SCALE OF FEET
CITY-WASTES DISPOSAL CO, ENGR'S.
OHIO STATE BOARD OF HEALTH

PLATE XXXVI.

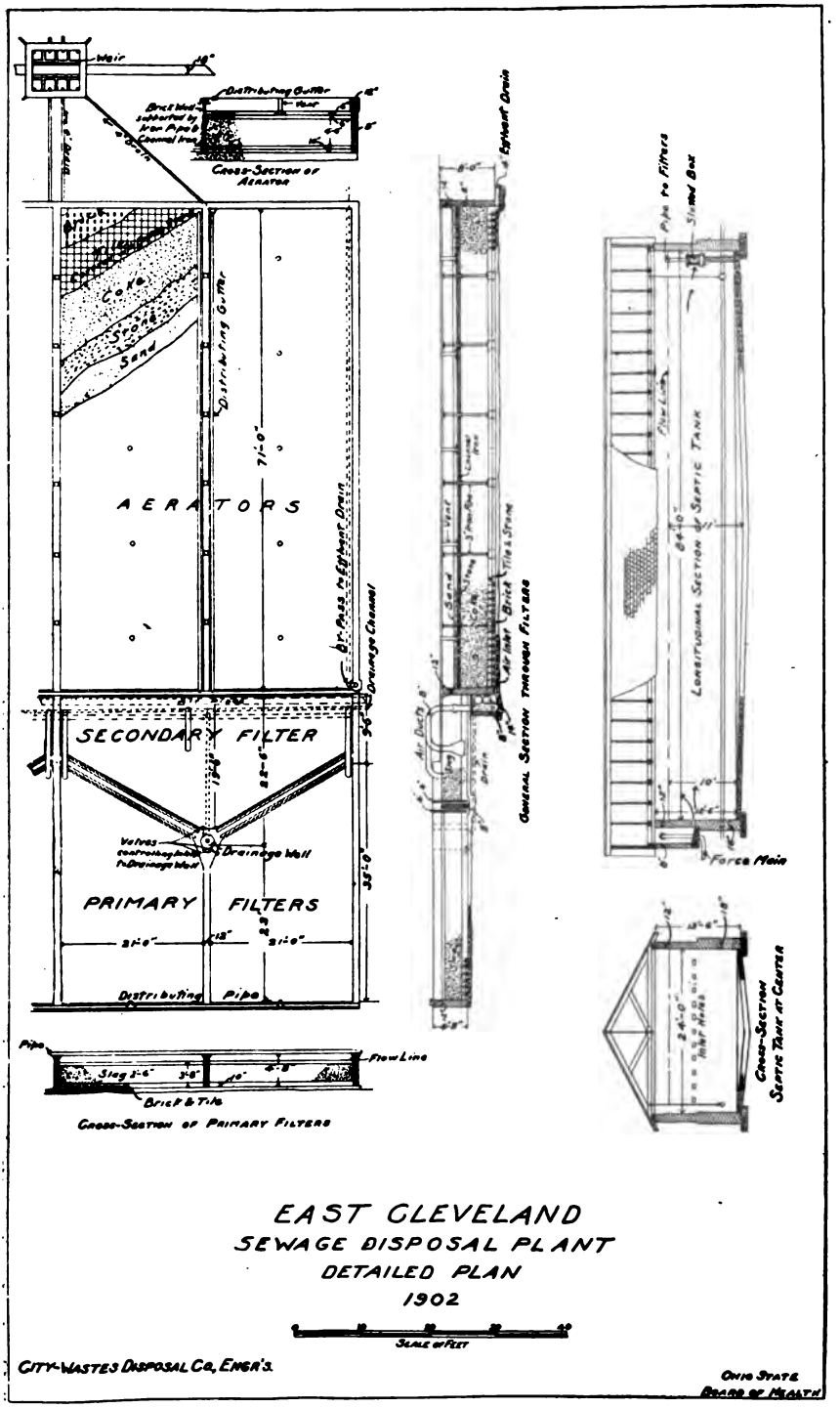


PLATE XXXVII.

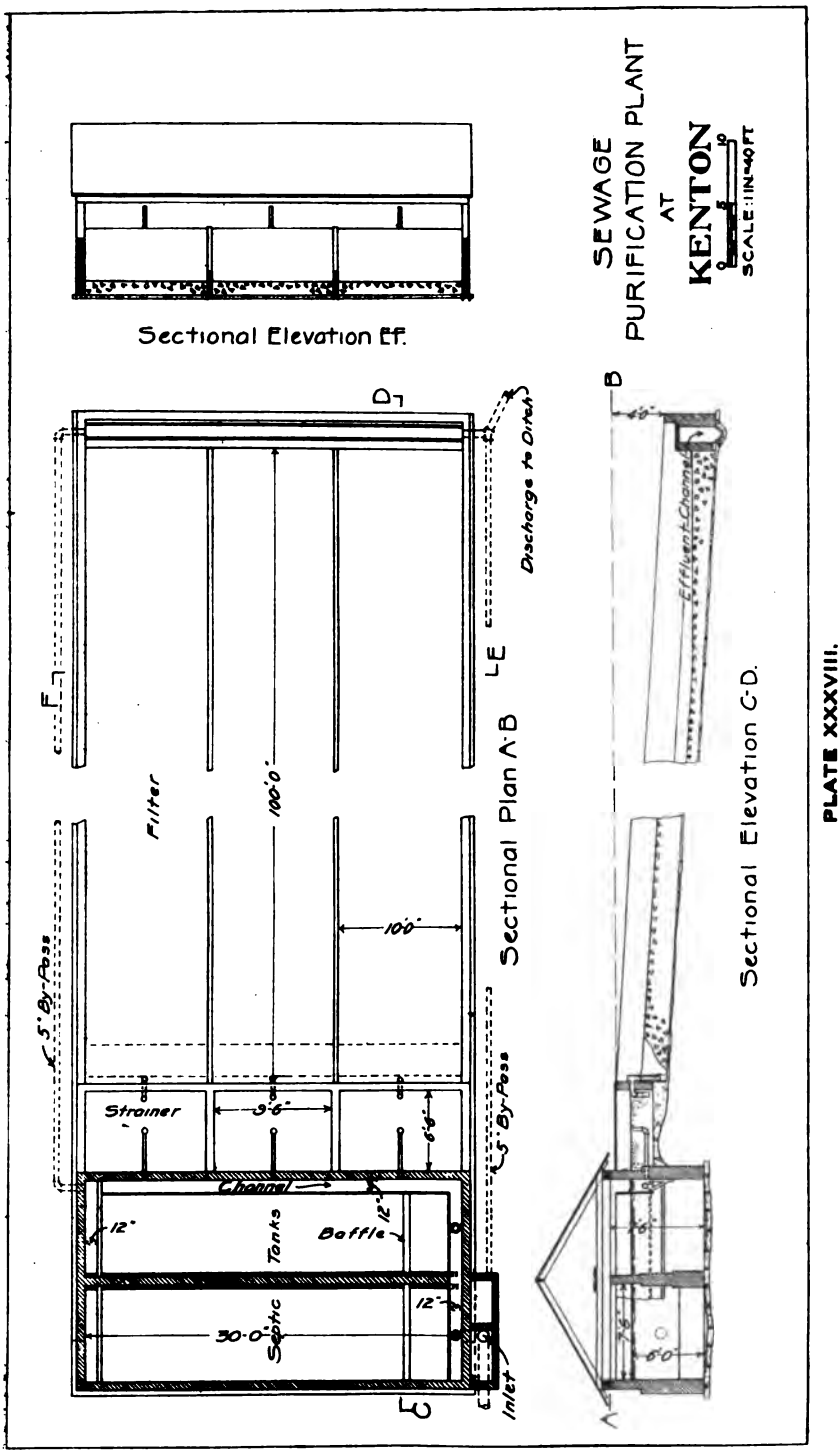
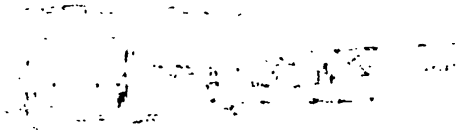


PLATE XXXVIII.



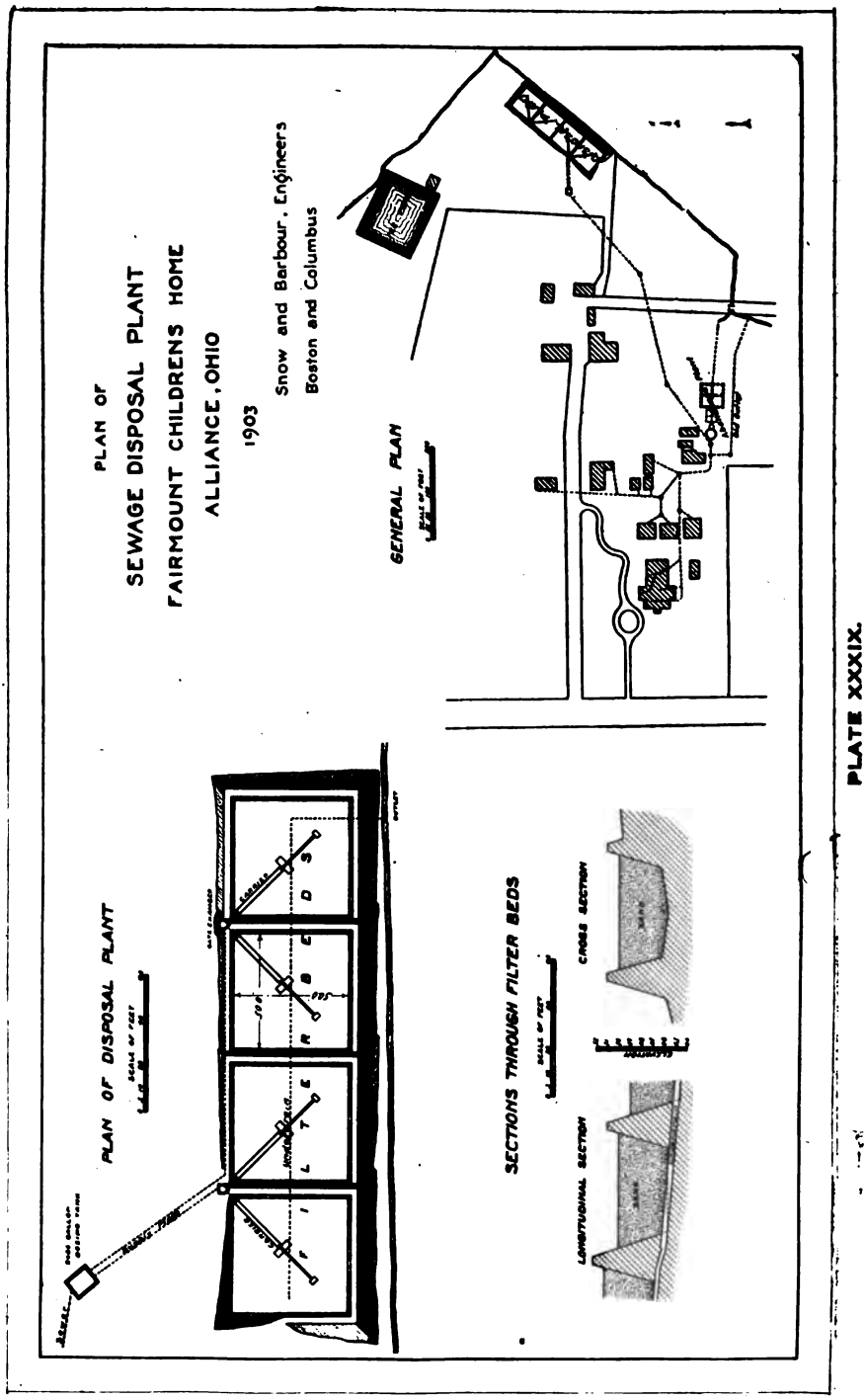

PLAN OF
SEWAGE DISPOSAL PLANT
FAIRMOUNT CHILDRENS HOME
ALLIANCE, OHIO
1903
Snow and Barbour, Engineers
Boston and Columbus
GENERAL PLAN
PLAN OF DISPOSAL PLANT
SECTIONS THROUGH FILTER BEDS
CROSS SECTION
LONGITUDINAL SECTION

PLATE XXXIX.

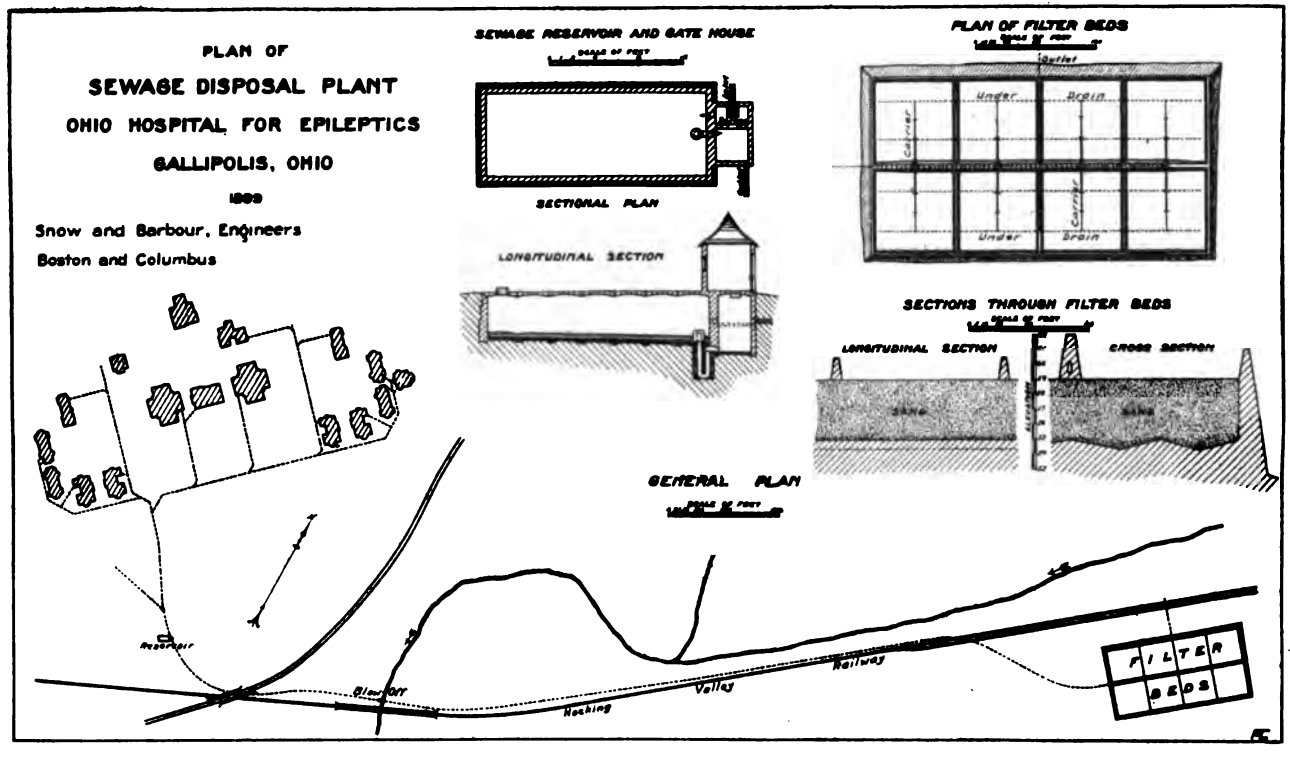

PLAN OF
SEWAGE DISPOSAL PLANT
OHIO HOSPITAL FOR EPILEPTICS
GALLIPOLIS, OHIO
1909
Snow and Barbour, Engineers
Boston and Columbus
SEWAGE RESERVOIR AND GATE HOUSE
SECTIONAL PLAN
LONGITUDINAL SECTION
PLAN OF FILTER BEDS
Under Drain
SECTIONS THROUGH FILTER BEDS
LONGITUDINAL SECTION
CROSS SECTION
GENERAL PLAN
Reservoir
Elm Fork
Hocking
Valley
Railway
FILTER BEDS

PLATE XL.

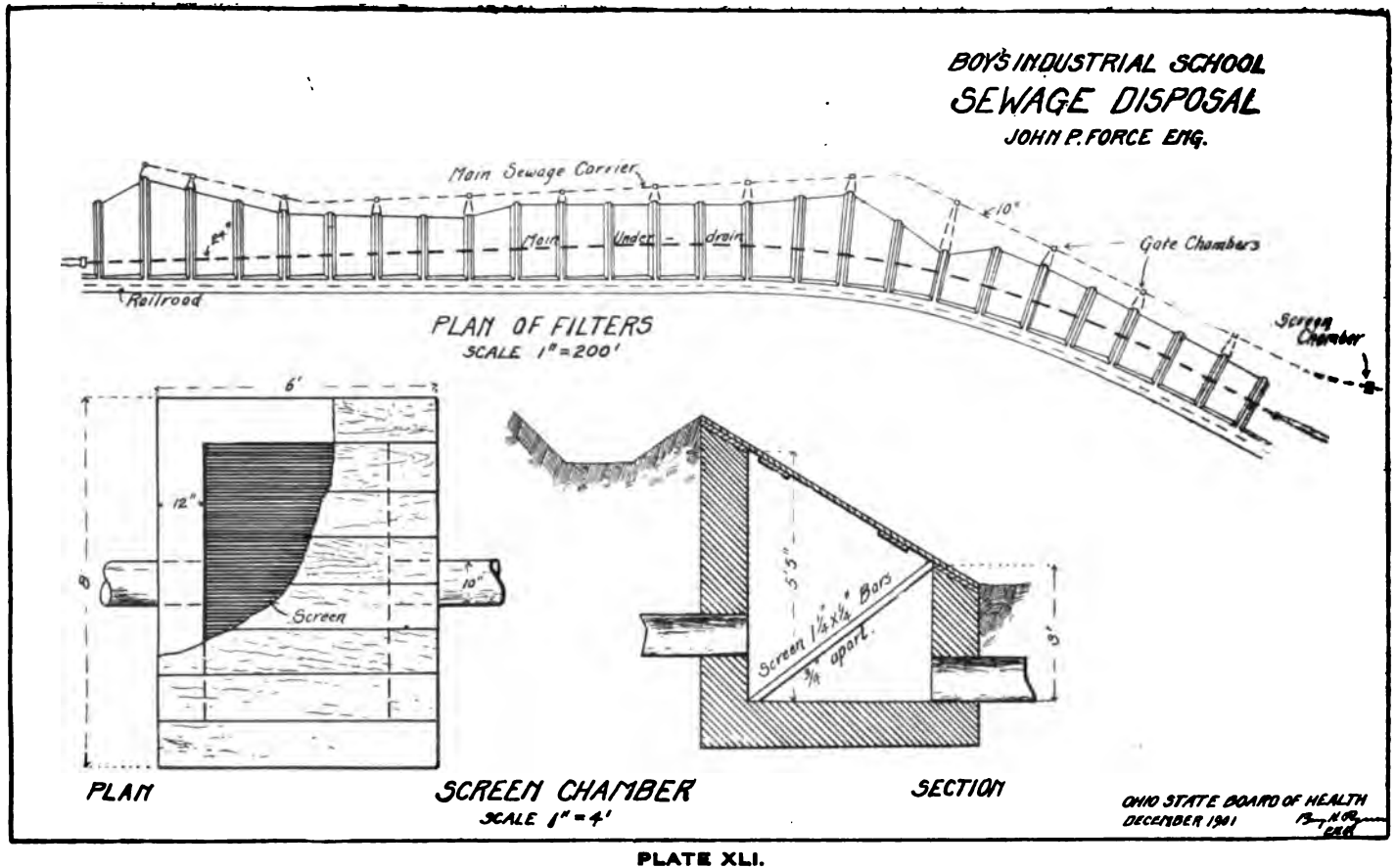

BOY'S INDUSTRIAL SCHOOL
SEWAGE DISPOSAL
JOHN P. FORCE ENG.
Main Sewage Carrier
Main Under drain
Gate Chambers
Screen Chamber
Railroad
PLAN OF FILTERS
SCALE 1" = 200'
6'
12"
8'
10"
Screen
5'5"
Screen 1½ X ½" Bars
¾" apart.
3'
PLAN
SCREEN CHAMBER
SCALE 1" = 4'
SECTION
OHIO STATE BOARD OF HEALTH
DECEMBER 1901

PLATE XLI.

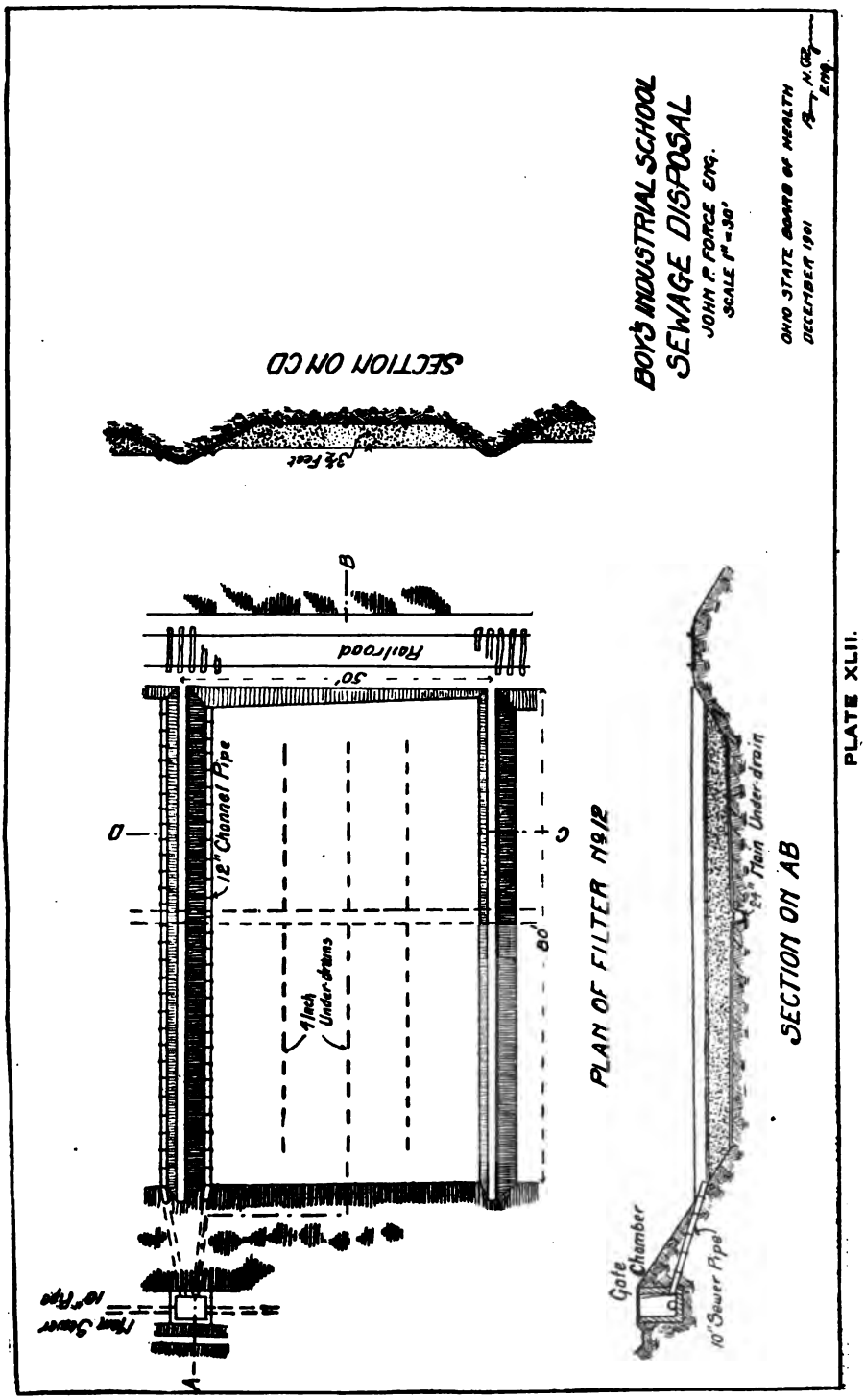

BOYS INDUSTRIAL SCHOOL
SEWAGE DISPOSAL
JOHN P. FORCE ENG.
SCALE 1" = 30'
OHIO STATE BOARD OF HEALTH
DECEMBER 1901
SECTION ON CD
24 Feet
PLAN OF FILTER No 12
Railroad
30'
12" Channel Pipe
4 Inch Underdrains
80'
SECTION ON AB
Gate Chamber
10" Sewer Pipe
4" Main Underdrain
Main Sewer
10" Pipe

PLATE XLII.

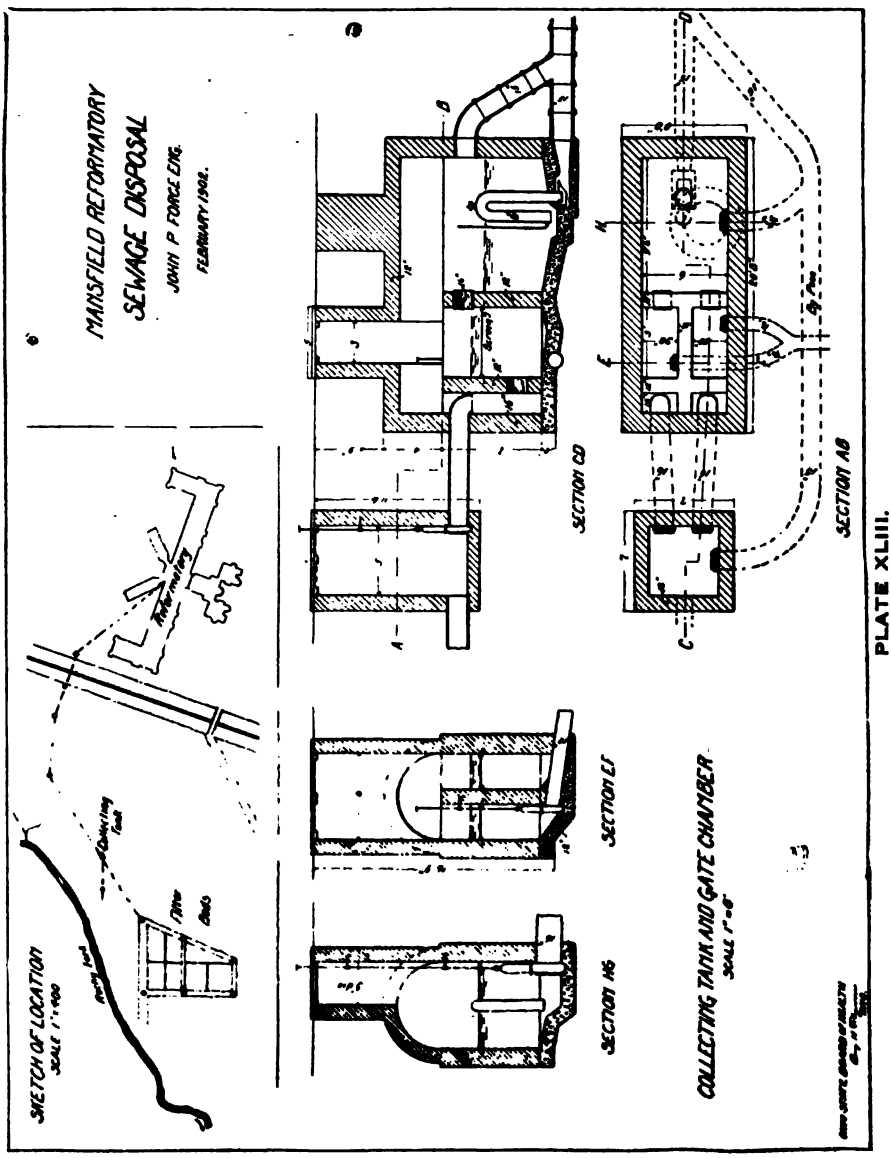

MANSFIELD REFORMATORY
SEWAGE DISPOSAL
JOHN P FORCE ENG.
FEBRUARY 1902.
SKETCH OF LOCATION
SCALE 1"=800
SECTION CD
SECTION EF
SECTION GH
SECTION AB
COLLECTING TANK AND GATE CHAMBER
SCALE 1"=8'

PLATE XLIII.

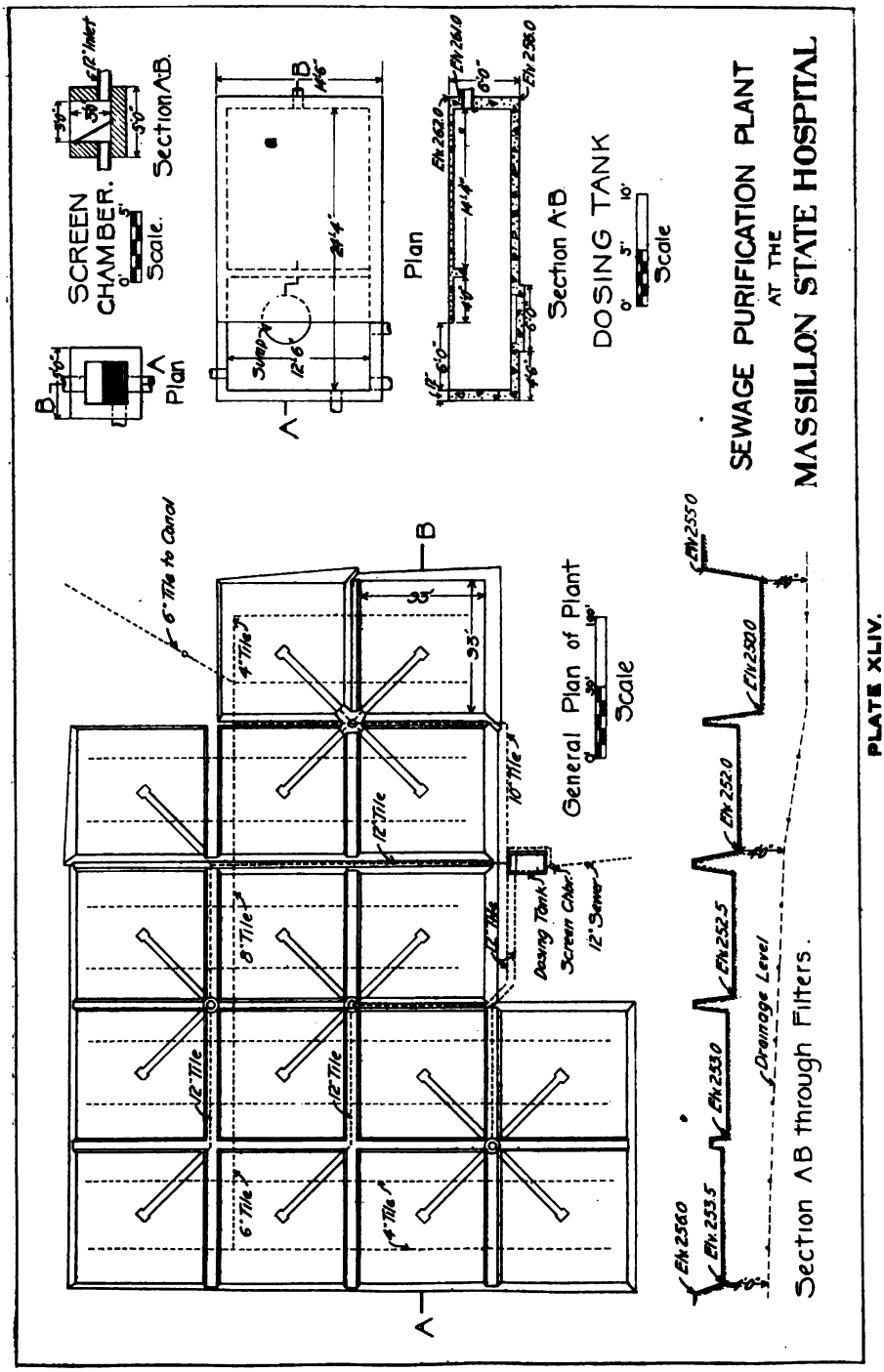

SEWAGE PURIFICATION PLANT
AT THE
MASSILLON STATE HOSPITAL
SCREEN CHAMBER.
Scale.
Section AB.
Plan
Plan
Section AB
DOSING TANK
Scale
General Plan of Plant
Scale
Section AB through Filters.
6" Tile to Canal
4" Tile
8" Tile
10" Tile
12" Tile
Dosing Tank
Screen Chamber
12" Sewer
Drainage Level
El. 2560
El. 2535
El. 2530
El. 2525
El. 2520
El. 2510
El. 2550

PLATE XLIV.

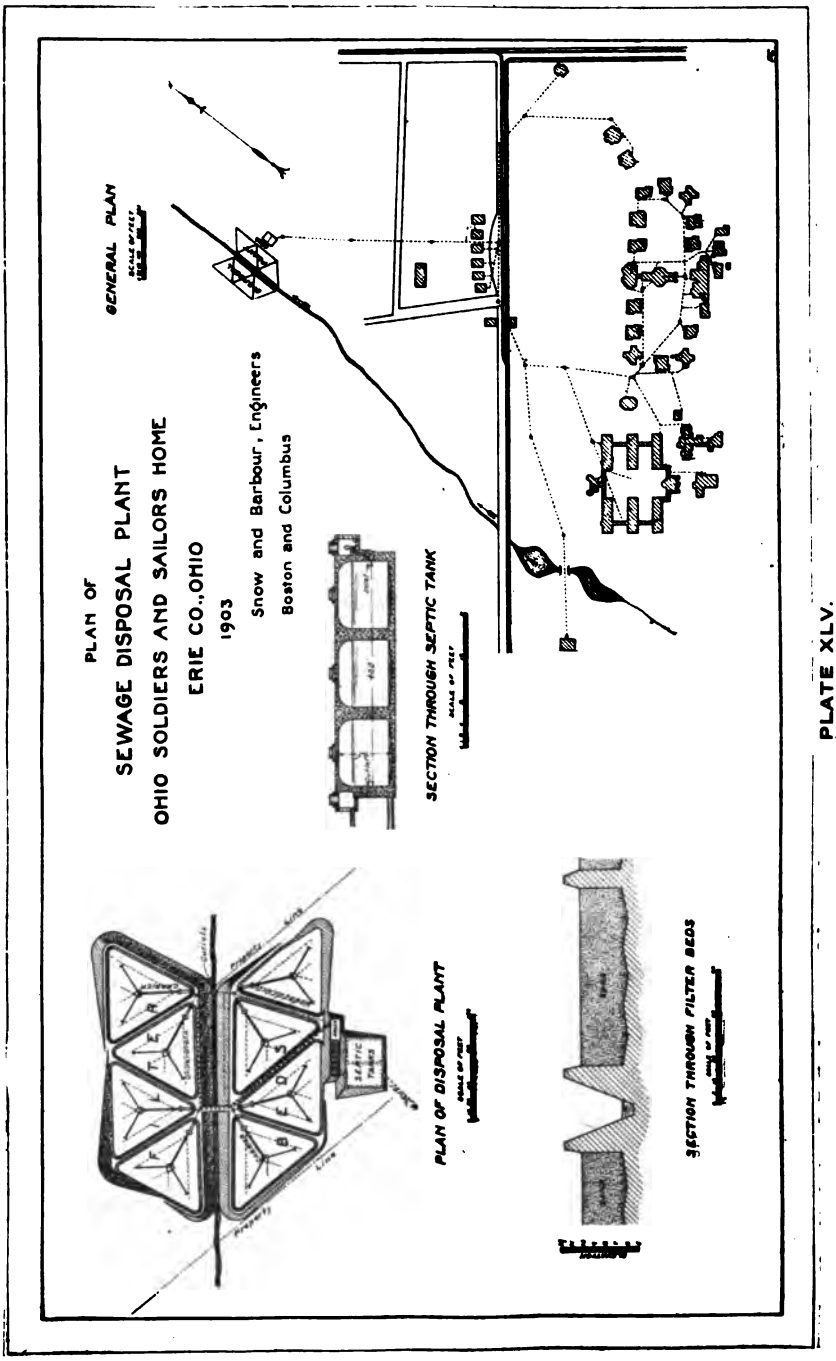

PLAN OF
SEWAGE DISPOSAL PLANT
OHIO SOLDIERS AND SAILORS HOME
ERIE CO., OHIO
1903
Snow and Barbour, Engineers
Boston and Columbus
GENERAL PLAN
SECTION THROUGH SEPTIC TANK
PLAN OF DISPOSAL PLANT
SECTION THROUGH FILTER BEDS

PLATE XLV.

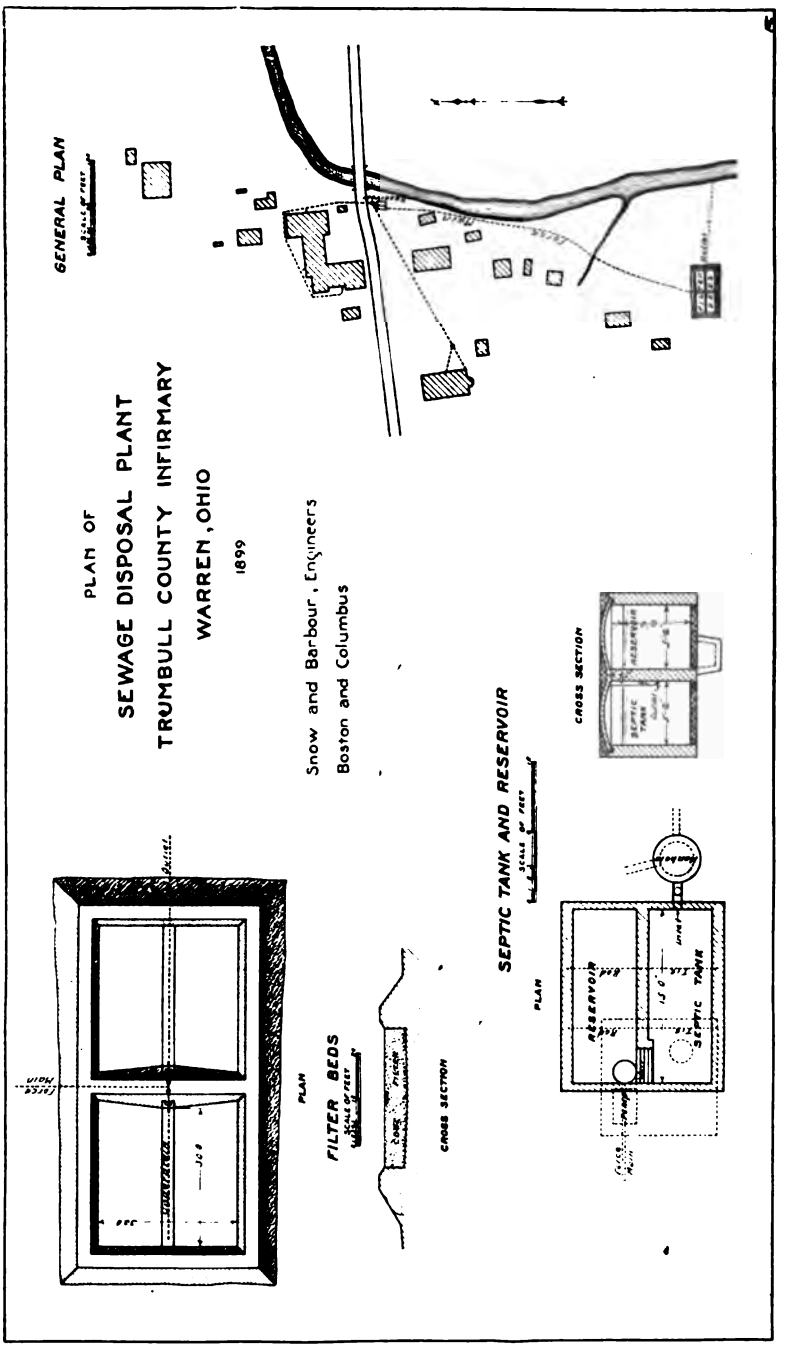
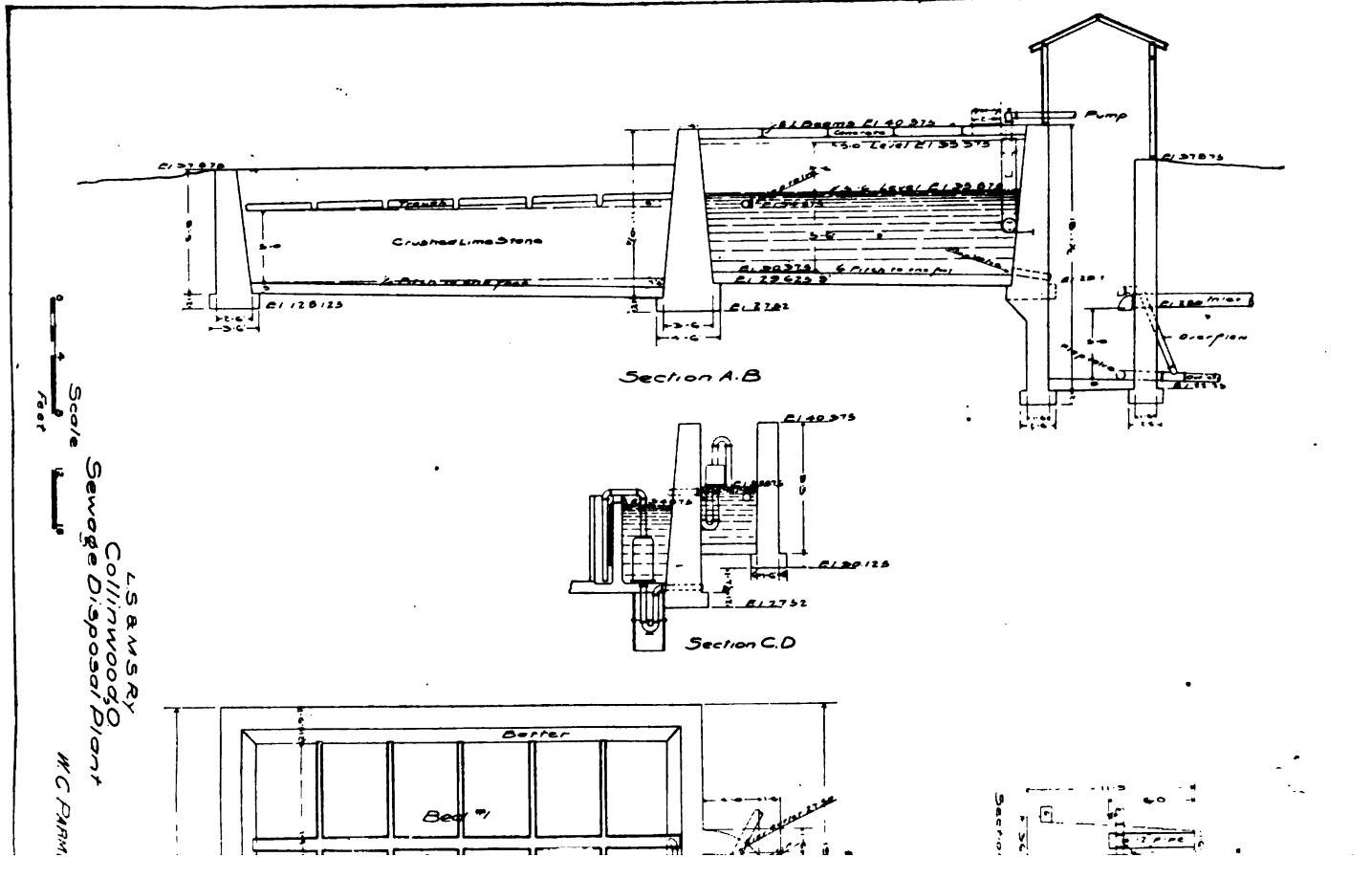
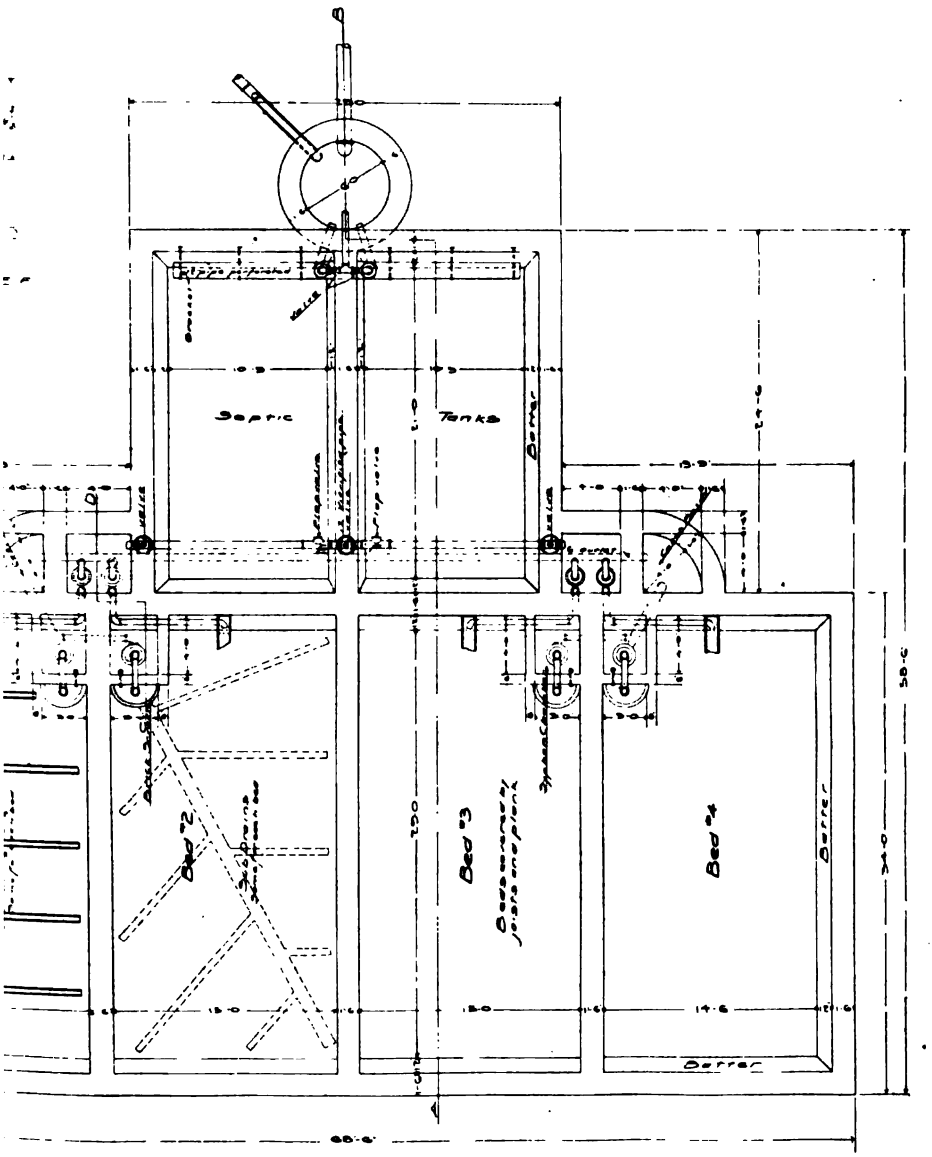

PLAN OF
SEWAGE DISPOSAL PLANT
TRUMBULL COUNTY INFIRMARY
WARREN, OHIO
1899
Snow and Barbour, Engineers
Boston and Columbus
GENERAL PLAN
FILTER BEDS
PLAN
CROSS SECTION
SEPTIC TANK AND RESERVOIR
PLAN
CROSS SECTION
RESERVOIR
SEPTIC TANK

PLATE XLVI.


Pump
Crushed Lime Stone
Section A.B
Section C.D
Baffer
Bed
Scale
feet
L.S. & M.S.R.Y.
Collinwood O
Sewage Disposal Plant
W.C. Parm



Plan

E.Y. Consulting Engr
Cleveland. O.

PLATE XLVII.

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